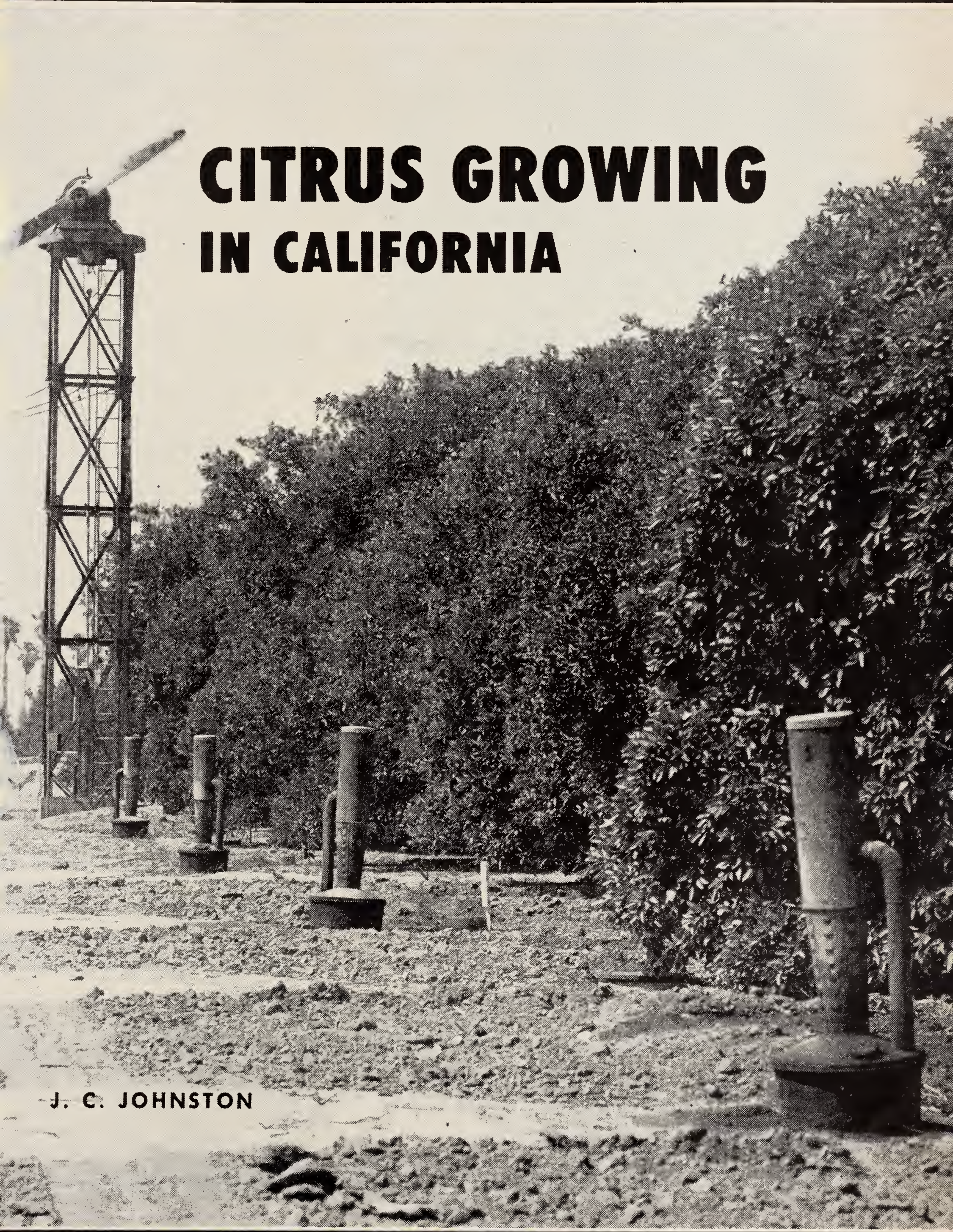
Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

CITRUS GROWING
IN CALIFORNIA



J. C. JOHNSTON

CALIFORNIA AGRICULTURAL
Experiment Station
Extension Service

CIRCULAR 426

C I T R U S G

J. C. JOHNSTON

CITRUS AREAS AND VARIETIES

This circular replaces Extension Circular 114

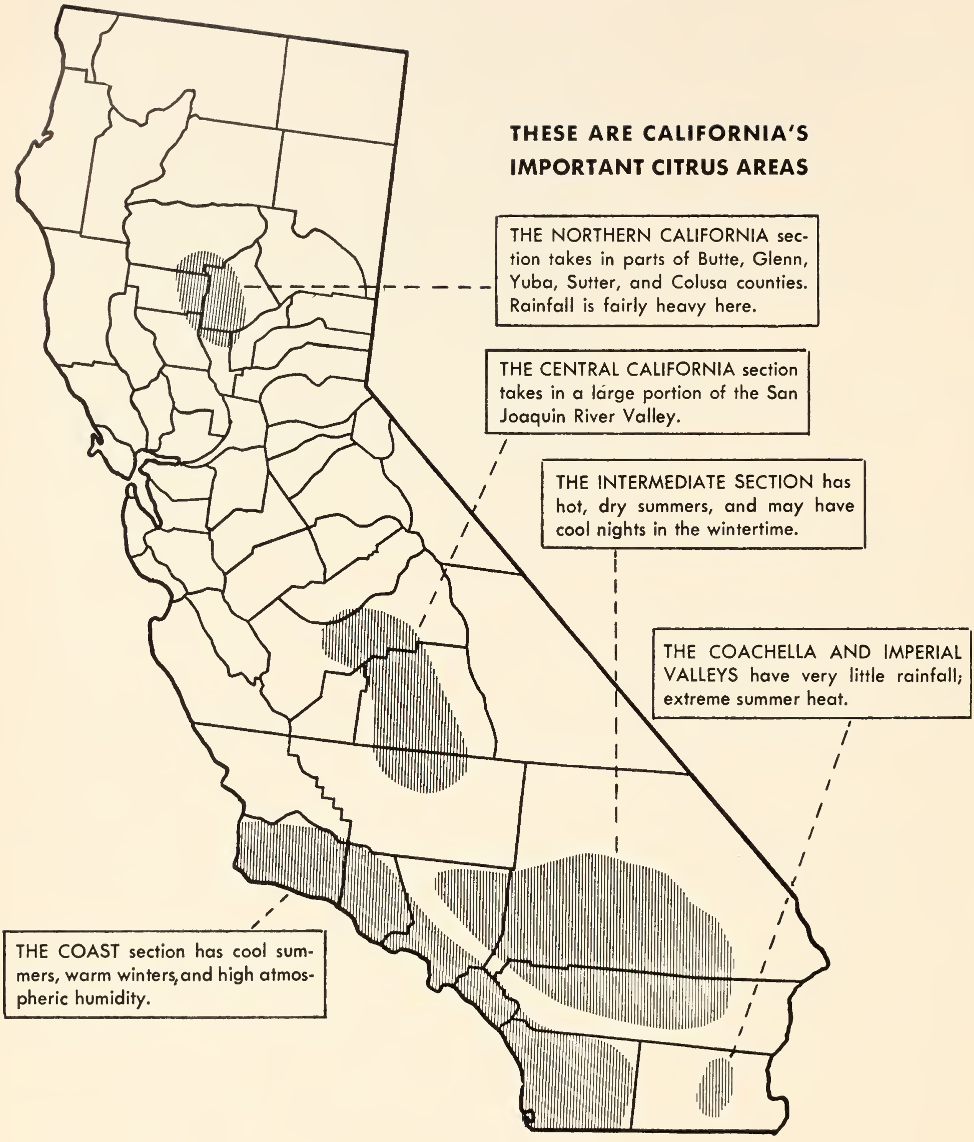
THE AUTHOR:

J. C. Johnston is Agriculturist (Citriculture) in Agricultural Extension, Riverside.

April, 1953

FOR SUCCESSFUL OPERATION FIVE STEPS ARE NECESSARY

THESE ARE CALIFORNIA'S IMPORTANT CITRUS AREAS



WHERE CITRUS IS GROWN . . .

in California. The region is 600 miles long . . . includes five areas.

Citrus fruits are grown commercially in California from San Diego County in the south to Glenn County in the north, a distance of approximately 600 miles. Within this area are five more or less distinct regions or climatic zones where citrus fruits can be produced. These are indicated on the map, opposite.

The coast section, comprising the southern California counties of San Diego, Orange, Ventura, and Santa Barbara, and the southwestern part of Los Angeles County, is characterized by an equable climate with cool summers, warm winters, and a relatively high atmospheric humidity due to close proximity to the Pacific Ocean.

The intermediate section includes Riverside and San Bernardino counties, and parts of Los Angeles County. It has hot, dry summers, bright days, and cool nights.

The Coachella and Imperial valleys have little rainfall and have extremes of summer heat and dryness.

The central California section, in the San Joaquin Valley, includes Kern, Tulare, and Fresno counties.

The northern California section is in the Sacramento River valley.

The last two citrus districts are climatically similar, each having hot, dry air and long, clear, sunny days in summer. In spring, fall, and winter prolonged periods of cold days are characterized by heavy dews and ground fogs. Rainfall, which increases as one goes north, is somewhat greater in the Sacramento River valley than in the central California section.

In the northern and central sections and in the Coachella and Imperial valleys, climatic extremes ripen the fruit earlier than in other parts of the state; for example, although the valleys of the San Joaquin and Sacramento Rivers are from 300 to 600 miles farther north than the southern California sections, oranges grown there can be marketed earlier than those from the south.

The climatic differences in the various producing areas have a marked influence on time of ripening. For this reason California can make shipments of oranges throughout the entire year by planting only two varieties. Shipments of Marsh grapefruit extend over a 10-months period. This makes better standardization possible and gives California an advantage over districts which must plant numerous varieties to extend the shipping season.

The shaded areas on the map show roughly the five commercially important citrus-growing areas in the state of California.

THE VARIETIES GROWN . . .

Most citrus is of three kinds—oranges, lemons, and grapefruit.

Oranges, lemons, and grapefruit are the important kinds of citrus fruit grown in California. Mandarin oranges and limes are produced in limited areas, and there are a few acres of citron. Their relative importance and distribution is shown in the accompanying tables.

Many other kinds of citrus fruit are grown in home gardens or for specialty markets, including kumquats, pummelos or shaddocks, Chinese lemons, sweet limes and lemons, and numerous hybrids.

Citrus trees make attractive ornamentals and in addition provide a variety of interesting and valuable fruit for the home garden.

Five varieties are used commercially

The California citrus industry is based upon five important commercial varieties: Washington Navel and Valencia oranges, Eureka and Lisbon lemons, and Marsh (Marsh's Seedless) grapefruit.

Acreage of Commercial Citrus Fruit Growing in California, 1951*

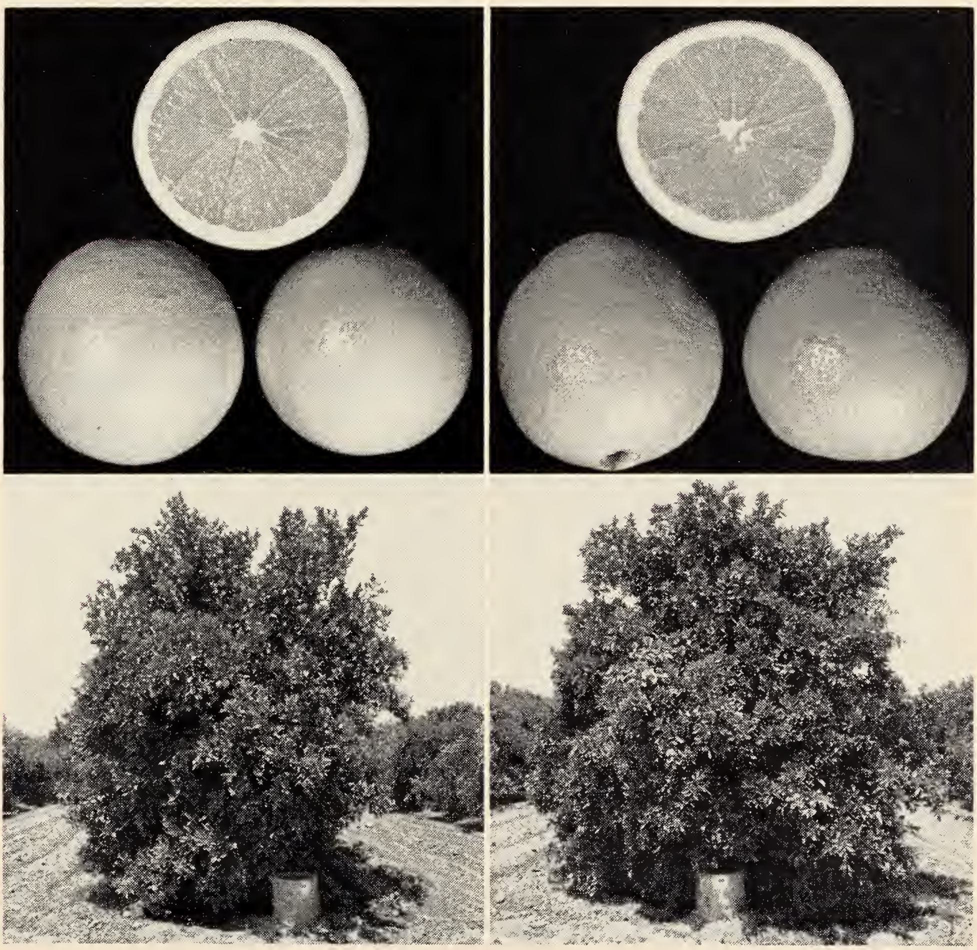
	Southern California	Central California	Northern California	Total
Oranges				
Bearing	166,065	40,207	2,137	208,409
Nonbearing	6,980	1,294	23	8,297
Total	173,045	41,501	2,160	216,706
Lemons				
Bearing	53,042	1,209	58	54,309
Nonbearing	7,048	96	0	7,144
Total	60,090	1,305	58	61,453
Limes				
Bearing	329	13	2	344
Nonbearing	1	......	......	1
Total	330	13	2	345
Grapefruit				
Bearing	9,046	405	8	9,459
Nonbearing	344	3	......	347
Total	9,390	408	8	9,806
Tangerines				
Bearing	614	87	2	703
Nonbearing	266	......	......	266
Total	880	87	2	969

* From California Cooperative Crop Reporting Service.

The Washington Navel orange. This variety is unequalled as a dessert fruit. Its excellent quality is due to its rich flavor, seedlessness, deep color, large size, and crisp flesh—all highly desirable in a commercial citrus variety.

The ripening period varies from year to year, according to temperature, but in general the first pickings are made during the period between November 1 and December 1. A large part of the fruit grown in the northern and central interior sections of the state is picked and shipped before the last part of December, when normal picking operations begin in the southern part of the state. Higher temperatures are responsible for the earlier maturity of citrus grown in the north.

The quality of the fruit of the Washington Navel is also markedly affected by differences in climatic environment. Cool, humid summers tend to produce large fruits which are slow to mature and are a much lighter orange color. In the desert areas yields are low, and although the fruit matures early it lacks the full, rich flavor characteristic of the variety. As a result, the best quality fruit is produced in foothill areas and other locations with warm nights, and hot—but not excessive—day temperatures. The regions of optimum growth and production are central California and the intermediate sections of southern California.



Top, left to right: Valencia and Navel fruits. Bottom, left to right: Valencia and Navel trees.

The acreage devoted to the Washington Navel has decreased slowly in recent years because the Washington Navel orange reaches market when fruit from other orange-growing sections is in heavy supply.

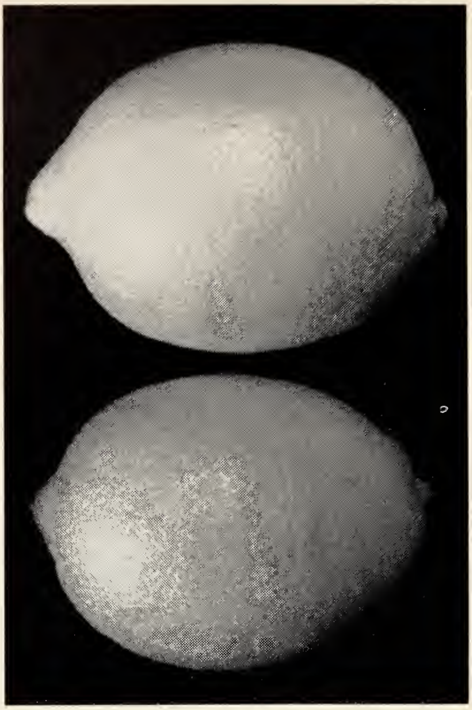
The Valencia orange. This is the leading orange variety in California. Unlike the Washington Navel, it produces well over a wide range of climatic conditions. The tree is vigorous and the fruit has high quality and attractive color and contains few seeds. Its juice is superior whether used fresh or in processed form.

Valencia oranges are harvested from April to November in southern California and slightly earlier in northern districts.

One difficulty with the variety is its susceptibility to a drying-out of the pulp vesicles when held on the tree too long after maturity, especially in the coast districts. Another disadvantage is that after the fruit is fully ripened and colored it has a tendency to return to a green color if it is left on the tree a long time. Both of these tendencies are physiological changes which take place in most citrus fruits when they are held on the tree after maturity. In spite of this deterioration, "tree storage" is preferable to commercial cold storage as it is known at present.

The Eureka lemon. The status of lemon varieties in California is confused. The principal varieties are Eureka and Lisbon, but within these varieties there is considerable variation. This is due partly to natural variation, and partly to the fact that lemon varieties are difficult to distinguish; and similar varieties become mixed because of careless bud selection. Consequently, it is wise to buy trees propagated from a variety which is known to produce good crops of quality fruit in the community where the orchard is to be planted.

The Eureka is a commercial lemon variety, popular principally because it bears fruit throughout most of the year. Although it is generally considered a spring and summer variety, the climatic extremes of the intermediate districts influence to some extent the time at which the fruit is produced.



The Lisbon lemon.

The trees of the Eureka are spreading, open, and moderately vigorous. They are more subject to frost injury than other lemon varieties now grown in California.

In general, the Eureka is best suited to the coast sections. Most of its fruit is borne on the tips of the bearing wood, where severe sunburn can result in the hot intermediate sections. Wind also causes considerable damage by scarring when the fruit is blown against twigs and leaves.

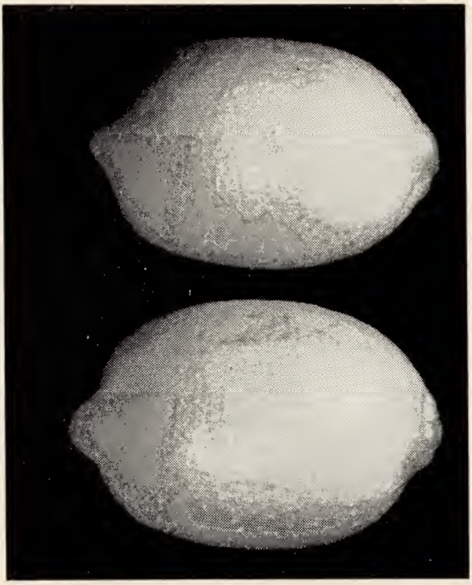
The old line Eureka lemon cannot be recommended for planting. It is a weak variety subject to shell bark and dry bark. Its productive life is usually short. Nucellar varieties (see below) derived from the Eureka are giving promising results and are suggested where a variety of Eureka type is desired.

The Lisbon lemon. This is well suited to all sections of California. It is a large,

vigorous, dense, spreading tree; its fruits are borne on the inside of the tree where they are well protected from sun, wind, and cold. Most of the fruit matures in the fall and winter, especially in the interior areas. Lisbon trees are thornier than those of the Eureka variety. Because of their hardiness, they are not so severely injured by cold weather as are trees of the Eureka variety, nor are they so seriously affected by extreme heat or strong desert winds. The Lisbon as an individual tree is usually much more productive than the Eureka, partly because of its greater size and bearing area. Hence with Lisbons fewer trees per acre should be planted than with Eurekas. The most popular of the Lisbon varieties are the Rosenberger, Monroe, and Prior.

The Marsh grapefruit. The commercial grapefruit industry in California is based upon the Marsh variety. Its popularity is due almost entirely to its seedlessness. The quality of the fruit is good and its shape makes it easy to serve. The Marsh variety is at its best in the desert areas, where it matures fruit of high quality in the winter and early spring. In the intermediate areas it matures more slowly and must be left on the tree until June or later to develop its best quality.

The Marsh grapefruit.



The Eureka lemon.

Nucellar varieties. Currently there is much interest in nucellar seedlings derived from commercial varieties. These seedlings retain the characteristics of the original variety, but they are much more vigorous and are free from the common virus diseases of citrus.

Seeds of most species of citrus produce two kinds of seedlings: the kind which results from pollination; and nucellar seedlings which are derived entirely from the fruit-bearing or mother parent.

The portion of a seed which develops into a seedling is called the embryo. It is produced by the union of a male or pollen cell and a female or egg cell. This sexually produced embryo inherits certain characteristics from each parent and is therefore unlike either, although it may closely resemble them.

In citrus seeds the development of a sexual embryo stimulates cells in the surrounding tissue to form additional embryos. This is why one citrus seed may produce two or more seedlings. These extra embryos are not the result of a sexual union but are derived entirely from tissues of the seed-bearing parent. Like buds, they reproduce the characteristics of the parent from which they were

derived. Seedlings of this kind are called nucellar seedlings because the part of the seed from which they develop is called the nucellus.

Nucellar seedlings are characterized by vigorous, upright, thorny growth. They are usually slow to come into bearing, but when they have reached maturity the growth becomes characteristic of the variety from which they originated, except that it is usually more vigorous. Trees propagated from bearing nucellar seedlings come into production about as soon as the parent variety.

Nucellar varieties have been developed from all of our commercial varieties. Because of their vigor they are very promising, but experience with them is limited and only time will tell what their value may be.

A nucellar Eureka lemon, developed by Dr. H. B. Frost, of the Citrus Experiment Station, has been widely planted and growers are optimistic over its future.

BUY THE BEST TREES POSSIBLE . . .

Select them in the nursery before they are dug . . . and get good ones.

Choose your trees carefully

Success in the production of citrus fruits is determined to a large extent by the vigor and inherent capacity of the tree to produce large crops over a long period of time. No combination of good soil and water, favorable climate, and skillful management can overcome the handicap of poor trees. For this reason it is wise to buy the best trees obtainable. Even a slight increase in production or length of life will quickly repay the small added cost of superior trees.

Study their general appearance. Good citrus nursery trees will have large, thrifty leaves and bright, clean bark. The bud union should be smooth and at least 6 inches above the soil level, to avoid possible infection by the organisms that cause gummosis. Avoid rootstocks which have stood in the nursery too long before budding; they are likely to be less vigorous. These older rootstocks can be identified by the dark gray bark and the marked difference in diameter between stock and scion. The scion should be nearly as thick as the stock.

It is always desirable to select trees in the nursery before they are dug. If the more vigorous trees are selected in this way, you can avoid getting weak trees or trees which have been picked over or left in the nursery too long. If the trees cannot be selected before digging, it will be best to get trees that have grown in one continuous flush. If growth has been checked at intervals, this will be indicated by joints or markings on the bark at points where growth stopped. Such trees are not necessarily undesirable. Growth may have been checked by climatic changes, by temporary lack of moisture, or by other external causes which have only a temporary effect on the trees. On the other hand, the cause may be a weak or incompatible rootstock or a diseased bud or root, in which case the trees would not be acceptable.

Age and size of trees are important. Citrus nursery trees are usually dug one or two years after budding. Most growers prefer one-year buds because it takes a good tree to reach marketable size in one growing season after budding. One-year buds can ordinarily be identified by leaves on their trunks, which older trees do not have. (Trees produced in the

Well-shaped navel tree one year old. Above: close-up of lemon tree showing good growth. This is a one-year-old budded tree from a nursery.

⬆ GET THIS . . . . NOT THIS ⬇

A second rate navel tree about two years old. Below: slow-growing nursery tree. Finger points at area of arrested growth.

hot interior grow more rapidly, and often shed leaves from their trunks before the end of the first growing season.)

The trees are graded according to the diameter of the trunk 1 inch above the union of the bud with the rootstock. Well-grown trees one year after budding should measure 3/8 to 3/4 inch in diameter, and trees two years after budding should measure 3/4 to 1 inch in diameter. For legal standards see Chapter 1148.95, Agricultural Code. State of California.

Do you want balled or bare-root trees? In California most citrus trees are removed from the nursery with a ball of soil, which is held in place by a wrapping of burlap. This practice preserves many of the small rootlets and enables the trees to make a quick start. It also prevents the roots from drying while the trees are being handled. For most purposes balled trees are to be preferred.

The balls should be 14 to 18 inches long to preserve as much of the root system as possible. They should be examined carefully, and any on which the soil has been broken away from the roots by careless handling should be rejected. The soil in the ball should be as nearly as possible like that in which the tree is to be planted; otherwise, it will be difficult to irrigate satisfactorily. It is best to avoid balled trees which have been stored more than a few weeks after digging.

Citrus trees are also dug with bare roots. This makes its possible to leave more of the large roots on the tree and permits inspection for disease or other defects in the root system. Trees which are to be planted immediately after digging can be handled more economically by this method. Trees that are to be shipped long distances are usually handled with bare roots. Citrus roots are very easily killed by drying, and the utmost care must be used in handling bare-root trees to keep the roots wet at all times by covering them with damp moss or other suitable material. They should not be kept in water; this often causes root injury.

Productive capacity cannot be judged by appearence. The buds should come from trees which are true to the variety desired, and which are known to be long-lived, productive, and free from disease. The rootstock and scion varieties should be congenial, and both stock and scion should be suited to the soil and locality in which the trees are to be planted.

Because it is necessary to take the word of the nurseryman as to the source of the buds and the kind of rootstock used, it is important to deal with experienced and reliable persons. It is also desirable to obtain a record of the location and registration numbers (see page 36) of the trees from which the buds were taken and also a record of the rootstock used.

Most commercial trees are budded on seedlings

Practically all citrus nursery trees grown in California are propagated by budding the varieties on rootstock seedlings. In most cases these seedlings are grown in a seedbed for one year, then transplanted to nursery rows where they remain for 6 to 12 months before they are budded to the desired varieties. The trees may be topped at about 30 inches to produce a head in the nursery, or they may be grown as whips and cut back when dug. The latter method is preferred by many growers because it results in a better balance between the top and root of the nursery tree. The trees are dug one or two growing seasons after budding and are known accordingly as 1- or 2-year buds. The age indicates the number of growing seasons after budding. A 1-year bud will usually be on a 3-year-old rootstock. The part of the tree growing from the inserted bud is called the bud or scion, and the part below the bud union is called the rootstock or stock.

Citrus trees may be propagated by other means such as cuttings, layers, and grafts; but it is doubtful if any other method than budding on seedlings will be

used for commercial propagation in California in the near future. While lemon cuttings root readily, trees now 18 years old are not so productive and, in the case of the weaker types of the Eureka variety, are less vigorous than budded trees on sweet orange and grapefruit rootstock.

Similar aged Washington Navel and Valencia orange trees on the other hand have proved to be as productive and vigorous as budded trees on sweet orange rootstock; but, unless they eventually show a marked superiority over the budded trees, the expense of special equipment and special care needed to root the cuttings is not warranted.

Select buds with great care. Citrus varieties are more or less unstable. Bud variations, or "bud sports," occur frequently. To date, few of the variations have proved to be as satisfactory as the established variety from which they rose. In addition, certain varieties which closely resemble the commercial ones have found their way into orchards through careless selection of buds. It is therefore necessary to use great care in selecting buds to see that they come from trees which are typical of the variety and which have a record of consistently high production and long life.

Citrus trees are subject to a number of virus diseases, such as scaly bark, which are carried to nursery trees by the buds used in propagation. To date, no remedy has been found for virus diseases, but they may be avoided by propagating from disease-free parent trees. The California State Department of Agriculture maintains a nursery inspection service and registers scaly bark-free parent trees to provide nurserymen with a reliable source of disease-free bud wood.

Be sure your rootstocks are suitable. The rootstock most commonly used in California at present is sweet orange. Grapefruit and Rough lemon are used to a lesser extent, and occasional propagations are made on trifoliate orange. Cleopatra mandarin is coming into use in place of sour orange, and Eureka lemons are sometimes propagated on Sampson tangelo.

Within the various species used as rootstocks are numerous varieties differing in their suitability. For this reason seed for growing rootstocks should come from old trees which have remained free from disease, and which are known to produce uniform, vigorous seedlings that make good trees when budded to the variety to be grown. Only limited quantities of such seed are now available, but the more progressive nurserymen own or have access to such trees.

The sweet orange is an excellent stock for all commercial varieties of citrus. Its chief disadvantages are its susceptibility to brown-rot gummosis and a tendency to produce somewhat smaller fruit than other common stocks. It is best adapted to soils ranging from light to medium loams, or loams which have good drainage. Because of its susceptibility to gummosis, sweet stock is not so well suited to clay loam or adobe soils.

The sour orange is hardy and resistant to many diseases. It has a deep root system which enables it to grow under a wide range of soil conditions, but it appears to be more susceptible to injury from excess moisture than sweet stock, possibly because its roots are deep. It has given good results with oranges and is especially favored for grapefruit.

In recent years, however, sweet orange varieties on this stock have been affected by the virus disease commonly called "quick decline." In experimental trials grapefruit on sour orange stock has also been shown to be subject to quick decline. This disease causes a rapid decline or sudden death of the trees. Needless to say, sour orange is no longer recommended as a stock for oranges or grapefruit. Lemon varieties are generally not satisfactory when grown on sour-orange rootstocks; however, in some localities sour stock is favored for vigorous lemon varieties on heavy soils.

The grapefruit has occasionally been used as a rootstock in California, especially for lemons. Its use is still experimental, however, for conflicting results have been reported from various districts. In trials at the Citrus Experiment Station in which the trees were propagated by using buds from a single parent tree, those budded on grapefruit rootstocks proved to be less productive than those budded on either sweet- or sour-orange rootstocks; in other trials the reverse has been true. Results in commercial orchards have been not only variable but also frequently unsatisfactory. As a rootstock for citrus trees, grapefruit should be used with caution.

In experimental trials sweet oranges on grapefruit stocks have shown symptoms of quick decline. Although the disease acts more slowly on this combination than it does when sweet orange is budded on sour orange, grapefruit cannot be recommended as a stock for sweet orange. According to field surveys lemon collapse occurs more frequently on grapefruit than on other stocks commonly used.

The Rough lemon, as a rootstock for commercial citrus varieties in California, cannot be recommended for general use. It has given good results with oranges on the lighter soils of the interior valleys, where the fruit is harvested early. Because of its vigor, this rootstock causes both tree and fruit to grow rapidly, but often the trees are short-lived. The fruit matures early but is low in both sugar and acid and often is coarse in texture. Valencia orange trees on roots of Rough lemon produce more granulated fruits than are normally found when other stocks are used. Both trees and fruit on this stock are more susceptible to cold injury than are trees on other rootstocks in common use.

The trifoliate orange has been used to some extent as a rootstock for a long time, but because of its slow growth and dwarfing tendencies it has not been favored for most of the species and varieties of citrus in California orchards. There are a number of very productive orange orchards on this stock, but in some cases the stand of trees is not uniform.

This is one of the hardiest of all citrus rootstocks. Both tree and fruit on this stock are more resistant to cold than on other stocks commonly used. However, trees on trifoliate stock are often stunted and unprofitable because of a disease called exocortis or "scaly-butt." This can most likely be overcome by selecting better varieties of trifoliate orange for seed, and by using buds from trees on trifoliate stock which are free from the scaly-butt disease and are not stunted. Trifoliate orange is resistant to brown-rot gummosis and does not appear to be affected by quick decline, but the evidence is not yet conclusive. Some varieties are also resistant to citrus nematode.

It is frequently used as a rootstock for ornamental citrus varieties and for home-orchards where small trees are desired. Fruit produced on trifoliate orange stock is of high quality and above average in size. Yields are heavy compared to tree volume. It deserves more consideration as a stock for oranges.

Cleopatra mandarin is coming into use as a stock to replace sour orange. It is resistant to fungus diseases, is compatible with most citrus varieties, and appears tolerant to the quick decline virus. Both yield and quality of fruit are good.

Troyer citrange and Sampson tangelo are hybrid varieties which are being tried as rootstocks. Oranges on Troyer stock are vigorous and resistant to cold, and the fruit is of high quality. Troyer citrange has shown outstanding vigor when compared to other stocks on old citrus soil. Its value as a stock for lemons and grapefruit has not been determined.

Sampson tangelo may have value as a stock for lemons where decline is a problem. Oranges on this stock are susceptible to quick decline. These stocks cannot be generally recommended yet due to lack of orchard experience with them.

CHOOSE YOUR LAND WITH CARE . . .

Prepare it well and plant to avoid as much trouble as possible at the start.

Location. The selection of the site for a citrus orchard will depend, to some extent, upon the variety to be grown. In general, however, the most important factors to consider are:

(1) adequate supply of good water;
(2) relative freedom from frosts and severe winds; and
(3) soil which is well drained and reasonably deep and fertile.

Water supply. California citrus districts are located in areas which are largely dependent upon irrigation for their water supply. The source of the water for this purpose is of primary importance. Growers in areas dependent upon water from wells have frequently had to deepen the wells and install new pumping equipment because of receding water levels. Many orchards have been seriously injured by irrigation water containing high amounts of salts or alkali. A permanent and adequate supply of water reasonably free from salts is of fundamental importance. The amount of water required is variable. It ranges from 18 acre-inches per acre near the coast to 6 acre-feet per acre in the desert valleys. The cost of water delivered to the orchard should not be excessive.

Carefully investigate water conditions before buying or planting an orchard, since remedies are expensive and frequently impossible to apply.

Frost damage. The possibility of frost damage is also a major consideration in the selection of an orchard site. The severe freezes of the past give evidence of the frost damage that may occur in supposedly frost-free areas. The lemon orchard site should be in a relatively frost-free area, since both tree and fruit are more tender than those of the orange varieties. Frost hazard depends upon local topography, the path of prevailing winds or minor air currents, and other local factors. The location of orchards of the various citrus varieties in any area is necessarily based largely on local experience with climatic suitability.

Wind damage. At certain seasons severe damage to citrus orchards may occur from hot, dry desert winds. Areas directly in the path of these winds should not be planted to citrus orchards unless effective windbreaks are provided.

Soil. The largest citrus areas are located on recent alluvial soils, nearly all of which have excellent underdrainage, are fairly deep and fertile, are easily cultivated, are free from injurious accumulations of salts, and are especially well adapted to the growing of citrus trees. Older types of soil are also used, and, although they are often shallow and contain hardpan, many of the orchards are vigorous and highly productive. Heavy clay soils usually produce vigorous and productive young orchards, but the trees are short-lived. Citrus trees are extremely susceptible to salt injury and should never be planted on land that has even a slight accumulation of saline materials.

Preparation of the land. No particular treatment is ordinarily necessary for good virgin soils other than the clearing away of native brush and the removal of rocks and other debris. If the land has been farmed, the tilth of the soil may be improved by growing a green-manure crop and plowing it under before the young trees are planted.

Rolling lands are now rather generally planted on the contour. Formerly the

practice was to scrape off the high spots to fill the lower areas. You should avoid this as much as possible to maintain an even depth of topsoil in all parts of your orchard. Scraped areas in an orchard frequently produce small, stunted trees and unprofitable sections. In laying out contour rows, some leveling may be necessary to permit a proper flow of irrigation water, but this type of work should be reduced to a minimum.

Before planting, grade the land carefully to assure an even distribution of water without washing of the soil. Furrows with a slope of 1 to 2 per cent are preferable on most soils. If the orchard is to be irrigated by sprinklers it can, in many instances, be planted without the natural contour of the land being changed. Avoid all unnecessary tillage or movement of soil.

Since young trees need water as soon as they are set, your irrigation system should be installed before planting begins, or adequate facilities to water from tank wagons during the first year or two should be provided. If you will give a preliminary irrigation after grading, the soil will settle and faults in the grade can be remedied before planting.

Give the trees a good start

Planting the trees. In California citrus trees are planted from early spring to early summer. Trees planted during the period from March to May inclusive continue to grow with but a slight check, and by the time cold weather begins new growth is sufficiently hardened to permit the trees to withstand low temperatures with a minimum of frost damage.

The most convenient plan for planting for all citrus orchard operations is the square system. When the contour system is used, the rows should be straight in at least one direction unless the contour of the land is too steep or irregular.

Planting distances. Distances at which the trees are planted depend upon the variety, type of soil, rootstock, and climatic influences; each of these factors has an important effect upon the size of the mature tree. The usual spacing for oranges and grapefruit is in rows from 22 to 24 feet apart, with the trees 20 to 24 feet apart in the rows. Lemon trees are planted in rows from 22 to 26 feet apart, the trees standing 18 to 22 feet apart in the rows. When grown on the same type of soil and on the same or comparable rootstocks, Eureka lemon trees need much less space that Lisbons. Washington navel orange trees need less than the Valencia orange or the Marsh grapefruit. Consider these points carefully before you decide upon planting distances.

For heavy production per acre, however, it is essential either to have large trees or to plant them rather close together. Double planting is the usual practice now, in order to increase yields in the first few years.

Remove the extra trees when crowding occurs. This system is especially good where there is a question as to the best rootstock to use. Two different rootstocks can be used by planting them in alternate spaces. When the trees begin to crowd, you can retain the stock giving the best results.

Use a planting board. The orchard site should be surveyed so that stakes may be accurately set to mark the spots in which the trees are to be planted. The use of a planting board, usually 4 feet long with a notch cut at the center and one at each end, aids in planting the tree accurately. Place the center notch of the board over the marking stake, and drive pegs into the ground at the notches in the ends of the board. Then remove the center stake and board, leaving the end pegs as guides for digging the hole and planting the tree.

The holes need to be deep enough only to accommodate the roots or ball of the tree, and wide enough to permit easy filling. If holes are unnecessarily deep, excessive settling will occur after planting.

After the hole has been dug, place the

planting board over it so that the planting pegs fit in the end notches; then place the tree in the hole, setting the trunk in the center notch of the board. The tree should be set in such a way that after settling it will be a little higher than it was in the nursery.

The uppermost roots should branch out at about the ground level. These precautions are important because trees set too deep are likely to be killed by brown-rot gummosis. The soil in the ball should be as nearly like the orchard soil as possible. Otherwise irrigation water may not penetrate the ball readily.

Attention to detail at this point will help to produce better mature trees later and make for a more uniform appearance.

When the tree is properly placed, fill the hole 3/4 full of soil and tamp it firmly around the ball. Next release the wrapping which covers the ball and fold it back so as to expose the top of the ball; now complete filling the hole.

Make a small basin (about 2 feet across) around the tree and irrigate thoroughly. Make the basin deep enough to hold 3 or 4 inches of water, and slope the bottom toward the tree trunk in such a manner that most of the water will penetrate the ball.

Planting should begin at the upper end of the row in order that water may be applied immediately. If after irrigation the trees are either too high or too low, they should be lowered or raised before the soil sets around their roots.

Wrap the trunks of young trees with newspapers, or with other types of tree protectors, to prevent sunburn or other injury to the tender bark during their first year of growth.

Try to prevent damage from disease or frost

In soils which have previously been planted to citrus, brown-rot gummosis may be especially serious unless unusual care is taken in planting. As an added precaution against brown-rot gummosis, young citrus trees are often planted on slight mounds or even on low ridges to keep their lateral roots at or near the surface of the ground. The trunks and top lateral roots may be treated with a thin wash of bordeaux mixture. Keep irrigation water away from the trunks, since the brown-rot fungus thrives in moist soils. This will be difficult during the first few irrigations, but if the trees have been properly planted and treated very little if any infection will occur.

Where these measures are not adequate, dip the ball of the tree in a 2-2-100 solution of bordeaux mixture (2 lb. of copper sulfate and 2 lb. of hydrated lime to 100 gal. of water) long enough to wet the outer surface of the soil in the ball.

Young citrus trees are likely to be damaged by frost and must be given protection for the first two or three winters in most regions. The usual method is to wrap the trunk and main branches in some material such as cornstalks. The wrapping should be 3 or 4 inches thick and snug enough to prevent free access of cold air to the trunk. It should cover only the trunk and the main limbs. Trees are fed by materials produced in green leaves in the presence of light. Therefore if the leaves are covered or shaded the tree is starved and becomes more susceptible to damage by cold. It is better to risk injury to the leaves by frost than to cover them and starve the tree.

THE ANNUAL CULTURAL PRACTICES . . .

Lay out a yearly program for the proper care of your orchard

Irrigation

In California irrigation is the most important operation in citrus culture. Citrus trees are evergreen and require soil moisture at all times; since rainfall is largely confined to the winter season, irrigation is necessary 6 to 12 months of the year.

The amount of irrigation water required varies from 18 acre-inches per acre near the coast to 36 or more acre-inches per acre in the interior. As much as 6 acre-feet per acre are used in some desert plantings. Climatic conditions are the principal factors determining the amount of water required, but soil type as well as size and vigor of the tree determine frequency of irrigation.

The irrigation season usually begins 3 to 6 weeks after the last winter rain and continues through the summer and autumn months until rain falls again. Available moisture should be maintained at all times in soil occupied by roots. This will usually be the first 2 to 3 feet. However, you must avoid unnecessary irrigation, especially on soils where drainage is slow and in the coastal areas where the trees remove moisture from the soil slowly.

Excessive moisture in the soil is a frequent cause of root decay, which in turn results in a serious decline in tree vigor and yield of fruit. On some soils good irrigation is not possible unless artificial drainage is provided. Most of the difficulty ascribed to overirrigation is actually caused by poor drainage.

Many soils contain large amounts of lime; on such soils the amount of water used must be reduced to avoid cholorosis (loss of green coloring matter from the leaves). In other instances the soil or water, or both, contain excessive amounts of soluble salts. Where this condition exists an occasional heavy irrigation, preferably by flooding, will leach a part of the salt from the soil.

It is important to know the quality of water used for irrigation. It should be free from injurious constituents, such as borax and sodium carbonate (black alkali), and should not contain an excessive amount of salts. As a general rule, hard waters are good for irrigation, and soft waters should be avoided.

Do not determine the time interval between irrigations by the calendar or by soil type, but base it on the rate of use by the trees. This will differ according to the season but can be determined by systematic observations of the soil occupied by roots. Apply water when most of the root zone is approaching dryness.

A good rule is "always irrigate dry soil, never irrigate moist soil." The use of a soil tube or an auger to test the soil for moisture at various depths should be a regular practice in all citrus orchards. The interval between irrigation usually ranges between 15 and 30 days.

The amount of water applied at each irrigation is determined by both the capacity of the soil to hold water and the depth to which soil is occupied by roots. Apply only enough water to wet the soil in the root zone. Water in excess of this amount will go below the reach of the trees and will carry soluble plant nutrients out of the soil.

Methods of irrigation. Irrigation water is commonly applied by furrows, basins, or sprinklers, usually supplied by underground pipelines.

In the furrow system, from 3 to 8

furrows are made for each row of trees, and the water is led into the furrows from a hydrant at the head of each row. The length of the furrow depends, to a large extent, upon the type of soil, but furrows of 300 feet or less are preferable. Water is usually run through to the end of the furrow and the valves in the hydrant adjusted so that little if any water runs off at the lower end.

Satisfactory penetration of water into the root zone requires from 2 to 72 hours depending on soil type. This should be determined by carefully conducted soil examinations. To minimize the difference in penetration between the upper and lower ends of the orchard, water should reach the end of the furrows in at least one fourth the time required for the desired penetration.

On fairly level soils with a uniform grade, wide-bottom furrows are coming into general use. Three or four shallow furrows, 18 inches to 2 feet wide, are made between each two tree rows. This method wets more of the surface and permits the use of larger heads of water without washing of soil; it also avoids deep tillage because only 2 inches of surface soil are disturbed in making the furrows.

On rolling land, contour furrows are much more efficient than straight furrows.

Basin irrigation. In very light sandy soils, the basin or check systems are used with a large head of water. The water is usually run to the lowest basin first and then worked back until finally the first or highest basin is filled.

The sprinkler type of irrigation is found in a few sections. The usual practice is to place the sprinkler heads on low portable standards connected by garden hose, or on portable aluminum pipes. These sprinklers throw the water over the square between four trees, very little water being thrown high enough to wet the trees. The entire line is moved after

Top: Narrow furrows in a tilled orchard. Bottom: Broad base furrows in a tilled orchard.

Above: Nontillage on a contour planting. Narrow furrows are best for this type of operation.

Below: Broad based, permanent furrows under nontillage.

Typical basin type of irrigation.

sufficient water has been applied. Usually there are enough lines of sprinklers to irrigate the whole grove in a reasonable length of time. The soil in contact with the tree trunk should always be kept as dry as possible to prevent gummosis.

Irrigation in alternate middles. The practice of irrigating in alternate middles is increasing in favor with citrus growers. The usual procedure is to divide the irrigation interval into two equal periods and apply half the water to alternate middles at each irrigation. The time between irrigations and the amount of water applied in any middle remains the same, but irrigation is twice as often.

For orchards on deep, permeable soil and with an ample water supply there is no reason to suggest the use of this method. It can be used to advantage, however, under the following conditions:

1) *On shallow soils where most of the root zone dries out at about the same time.* On such soils the interval can, in some cases, be adjusted to compensate for different climatic conditions provided water is available on call. Where this is not possible, serious wilting can be avoided by irrigating alternate middles. An attempt to overcome wilting by using more water at the regular interval may cause root damage.

2) *On heavy clay soils and in cases of poor drainage.* Where root injury has occurred or is likely to take place, the soil can be dried out more completely between irrigations without subjecting the trees to serious wilt.

3) *When the fixed interval between irrigations is too long.* In some water districts, the interval is fixed. This period may be too long for certain soils. Arrangements can sometimes be made to obtain half of the allotment at the usual time and half in-between so as to permit irrigation in alternate middles.

4) *Where there are numerous replants.* If irrigation is in alternate middles, water can be cut in to the replants from both sides. In this way the replants can be irrigated twice as often as when the water is applied all at one time.

5) *On calcareous soils where chlorosis is a problem.* A practical control for lime-induced chlorosis in many cases is to use less water. By irrigating alternate middles, the soil can be dried out more thoroughly without serious wilting.

6) *When there is a serious shortage of water.* The use of alternate middles under these conditions avoids the acute water deficit which occurs toward the end of the irrigation interval and enables the trees to remain in fairly good production. Instead of feast and famine, the water is rationed. There is a moderate but more or less continuous water deficit in the tree.

If the purpose of using alternate middles is to utilize a reduced irrigation supply, then the amount of water available for each irrigation should be applied to only as much soil as can be wet to the full depth of root activity. In this way the loss from surface evaporation will be minimized.

Where there is a salt problem as well as a water shortage, it is especially important to limit the area of soil which is wet in order to avoid salt accumulations. Shallow irrigation causes salts to build up in the soil.

The suggestion is often made that alternate furrows be used instead of alternate middles. This is all right in theory, but in practice there are many spots where water from one furrow penetrates into the adjacent furrow. These areas are wet at each irrigation, and the purpose of the method is defeated.

Others suggest that the water be used in the same middles each time, leaving alternate middles dry all season. If only one side is watered, the tree will not show serious wilt because water absorbed on one side is available to all parts of the tree. On the other hand, minerals absorbed on one side are not readily transferred to the other side. For this reason it is wise to irrigate on both sides of the trees in order to utilize more completely the fertility of the soil.

It has been further suggested that the practice of irrigating in alternate middles would cause root injury because the roots would become too dry. This is obviously not true because citrus roots are nearly always most abundant in areas where no irrigation water is applied. As we stated above, water is available to all parts of the tree including roots. The atmosphere in a soil at the wilting percentage is near 100 per cent relative humidity. Therefore roots in dry soil are not exposed to drying conditions.

Fertilizers

The fertilization of citrus orchard soils in California is of vital importance. The great variation in the soils of the different citrus-growing sections makes soil improvement an individual orchard problem. Orchard experience and experiments in fertilization indicate a general need for nitrogen and usually for organic matter. Practically all soils in the citrus districts are well supplied with available potassium, but phosphorus is needed in some.

The soil may be regarded as a storehouse which contains all the elements required for plant growth. Some of the materials in this storehouse may be reduced to such a low level that plants do not obtain enough for their most profitable performance. Then it is desirable to add the elements which are lacking so that the storehouse will again be supplied with the food elements required to produce the crop. It is not necessary or desirable to add all the elements needed by the plant, only to restore those which have been depleted.

At first glance it would appear feasible to determine deficiencies in orchard soils by means of chemical analyses, but this method has little value. This is due in part

to the variability of California soils and to the difficulty of obtaining a representative sample typical of the whole grove.

Furthermore, some elements may be present in a form unavailable to citrus trees, for even though the chemist can easily determine the total amount of mineral elements in the soil, no test has as yet been devised which will determine their availability to plants. It is therefore of little interest to determine the total amounts of plant-food elements present in the whole soil mass. Fertilizer requirements can be judged best by plant responses.

Organic materials may be used to furnish part of the nitrogen required, but the best results are obtained when half or more of the nitrogen is supplied from a chemical source. Nitrogen from many chemical sources has been tried. Most of these materials, when used excessively, have caused reduced water penetration. The most profitable amount of nitrogen to use differs between groves because of variations in age of trees, soil type, and cultural methods. It usually ranges between 1 and 3 pounds of actual nitrogen per tree. The amount must be adjusted up or down according to individual experience.

Organic materials have a very important place in citrus fertilization, chiefly because of their favorable effect on the physical properties of the soil. Organic matter increases the permeability of soil to water and thus improves the efficiency of irrigation. It counteracts the tendency of tillage to cause soils to run together, or to puddle and form plow sole. The more often soil is tilled the greater is the need for organic matter. It also counteracts the tendency of certain chemical fertilizers to seal the surface and prevent penetration of irrigation water.

In addition to improving the physical properties of the soil, organic matter such as manure carries nitrogen, phosphorus, potash, and many other minerals. Nitrogen from organic sources is not so completely available to plants as chemical nitrogen, but it is released slowly as decay takes place and is made available over a considerable period of time. This process results in a sustained effect especially desirable on sandy lands susceptible to leaching.

Covercrops or weeds, if grown in the winter, offer little competition to citrus trees and produce a very desirable kind of organic matter at minimum cost. They grow on the land and therefore add no minerals to the soil as do manures, but they conserve fertility because soluble nutrients are absorbed during the rainy season and returned after danger of leaching has passed.

A very heavy covercrop tends to compete excessively with the trees, particularly if it is permitted to grow late into the spring. There is no indication that the benefits to the soil are greater than with a moderate growth.

Nonleguminous covercrops require nitrogen fertilizers. Ordinary weeds, mustard, malva, cereals, and similar crops take their nitrogen from the soil, whereas leguminous covercrops, such as melilotus and vetch, take a portion of their requirement from the air. For this reason leguminous covercrops are preferred.

Phosphate fertilizers. Citrus trees respond to phosphate fertilizers in some localities, principally in shallow, acid soils. Lemons have shown a greater need for phosphorus than oranges. We have also learned that on some soils which have been without manure for a long time potash fertilizers have slightly increased the size of oranges. The evidence so far indicates that the cost of the potash required is greater than the benefits derived.

Over wide areas of California, citrus trees are unable to obtain enough zinc from the soil. This results in the deficiency symptom known as mottle-leaf. In limited areas an inadequate supply of copper causes the symptom known as exanthema. Manganese is also lacking in

many localities, but its deficiency affects the tree and crop less seriously than does a deficiency in zinc or copper. It is therefore profitable to use manganese only in the more severe cases of deficiency. In California zinc, copper, and manganese are most effective applied as sprays to the leaves.

Soil amendments. In addition to the fertilizer elements mentioned above, certain soil amendments are occasionally used by citrus growers. Sulfur and gypsum are most effective when used to counteract black alkali, but this form of alkali is very rare in citrus orchards. In a number of instances sulfur was used in sufficient amounts to make the soil acid, with no favorable result in yield or tree condition, so far as could be observed. It has even been known to have an unfavorable effect on soil structure. Lime (calcium carbonate) is an alkaline material which may increase the alkalinity of soils, but it does improve tilth on some soils and is useful where excessive amounts of sulfur or other acid-forming materials have been applied.

Sulfur is usually to be preferred on soils with a high content of lime, and gypsum on soils with low lime content. It is always wise to apply the material to small areas and observe the result for a year or two before treating the whole place. Most citrus soils will not be improved by these materials.

Chemical nitrogen fertilizers. Those commonly available are calcium nitrate, sodium nitrate, ammonium sulfate, ammonium nitrate, urea, and liquid ammonia gas. Nitrogen in the nitrate form penetrates the soil readily and is carried down as far as the water in which it is dissolved penetrates. It is therefore a good form of nitrogen to use, especially where quick penetration is important.

Nitrogen in the ammonia form becomes insoluble on contact with the soil and remains fixed in the surface until it is transformed into the nitrate form by soil organisms. This slower penetration is desirable on open sandy soils, where the fertilizer is likely to be carried below the root zone before it can be utilized. When applied to alkaline soils, there is some loss to the air from exposed surfaces.

On certain soils low in calcium and organic matter, chemical nitrogen carriers (calcium nitrate excepted) may reduce the rate of water penetration. This effect can usually be avoided by reducing tillage, growing winter covercrops, using manure, and distributing all fertilizers evenly over the entire area. In extreme instances an application of calcium in the form of gypsum may be helpful, but this will not usually be necessary in California, where most soils and irrigation waters contain an abundant supply of calcium.

Both calcium nitrate and sodium nitrate carry 16 per cent nitrogen, all in the nitrate form. Both chemicals are either broadcast or dissolved in irrigation water, and are excellent sources of nitrogen, especially for a quick response. On soils subject to leaching, the best results will be obtained if the amount to be used is divided into several small applications. There is some evidence that nitrogen in the nitrate form is more effective for citrus fertilization than other forms.

Ammonium sulfate carries 20½ per cent nitrogen, all in the ammonia form. It is either broadcast or dissolved in irrigation water and is a very good source of nitrogen, especially for light soils, which are subject to leaching. Since it is injurious to concrete pipe lines, a solution of this chemical in irrigation water should be kept dilute and the pipe lines flushed out after each application.

Ammonium nitrate carries 32½ to 33½ per cent nitrogen, half in the nitrate form and half in the ammonium form. Therefore half the nitrogen penetrates the soil readily, and half is fixed in the surface until changed to the nitrate form; this is an advantage when both quick and

sustained effects are desired. It can either be broadcast or dissolved in irrigation water.

Liquid ammonia carries 81 per cent nitrogen, all in the ammonia form. It is a gas reduced to liquid form by pressure, sold in steel cylinders. It dissolves very rapidly and is well suited for use in irrigation water. However, a certain amount is lost to the air when exposed in the irrigation furrows.

Urea carries 43 per cent nitrogen and penetrates the soil readily, but it is very unstable and is rapidly changed to ammonia by soil organisms and by the enzymes which they produce. For this reason urea acts very much like ammonia when applied to the soil, except that its initial penetration is somewhat greater.

On most soils the differences described above are not important. *Buy on the basis of cost per pound of actual nitrogen.*

Organic materials. The principal organic materials used in California citrus orchards are animal manures, alfalfa hay, and bean and cereal straws. The fertilizer value of these materials is variable; representative analyses, however, are given below to indicate the usual content of various elements, and especially to emphasize the fact that plant residues contain large amounts of phosphorus and potassium, in addition to the organic matter and nitrogen for which they are usually purchased.

The organisms which cause decomposition of organic matter in the soil require both nitrogen and organic matter for their activities. When organic matter is present in abundance, and the nitrogen supply is limited, decay proceeds slowly. The available nitrogen is built into the bodies of the organisms and remains unavailable to plants until most of the organic material is consumed and the organisms disintegrate.

On the other hand, if nitrogen is available in amounts greater than required by the organism, the decay process will be rapid, and the excess nitrogen will be available to the plants during the process. This is the basis for the statement that *organic materials may be used to furnish part of the nitrogen required for citrus*

Typical Analyses of Principal Bulky Organic Materials

Material	Per cent nitrogen	Per cent phosphoric acid	Per cent potash	Organic matter	Water	Ash
Dairy manure	0.80	0.44	1.37	30.5	32.7	36.7
Feed-yard manure (cotton-seed fed)	2.05	0.54	1.92	57.9	14.5	27.6
Feed-yard manure (alfalfa fed)	1.36	0.65	2.71	48.7	16.8	34.4
Poultry droppings	4.17	3.15	1.58	74.0	8.3	17.8
Poultry manure*	2.08	1.87	1.16	52.1	12.5	35.4
Rabbit manure	2.25	1.35	0.83	60.0	5.5	34.5
Hog manure	2.23	2.09	1.01	62.4	10.0	27.6
Sheep manure	1.39	0.96	2.09	52.5	9.0	38.5
Alfalfa hay	2.46	0.60	2.09	83.6	8.3	8.1
Alfalfa straw	1.30	0.30	1.80	82.0	8.5	7.9
Lima bean straw	1.20	0.25	1.28	82.4	8.5	8.8
Blackeye bean straw	1.00	0.25	1.90	82.0	8.6	9.4
Grain straw	0.60	0.33	1.38	86.1	5.8	8.1
Horse manure	0.77	0.52	1.50	70.4	14.4	15.2

* Droppings and floor litter.

trees, but the best results are obtained when half or more of the nitrogen is supplied from a chemical source.

The composition and value of animal manures vary according to kind of animals and kind of feed, as well as the conditions under which the materials are collected and stored. Manures from dairies usually contain from 0.50 per cent to 1.25 per cent nitrogen. The nitrogen content of feed-yard manures usually varies between 1 and 2¾ per cent. Other manures are subject to similar variation. All of these materials, with the exception of the better poultry manures, must be supplemented with chemical nitrogen for best results.

Alfalfa hay is occasionally used as a source of both nitrogen and organic matter; it has a nitrogen content of 2.0 to 2.5 per cent for the better grades, and from 1.0 to 1.5 per cent for the lower grades. Good, clean alfalfa hay is usually too expensive compared with other types of fertilizer; and the lower grades do not compare favorably with manure.

The nitrogen content of bean straw varies from 1.0 to 1.5 per cent, with a relatively high percentage of organic matter. Lima bean straw contains more nitrogen than blackeye bean straw. These straws are high in potash but low in phosphate and are valuable mainly as a source of organic matter. Be careful in buying bean straw; it usually contains weed seeds. Benefits from the use of such straws may be largely offset by the expensive eradication measures necessary for control of morning glory, puncture vine, and other noxious weeds. The expense of weed eradication should be charged against the fertilizer which introduced the seeds.

Grain straws are very low in nitrogen and high in organic matter. For this reason large amounts of supplementary nitrogen are required, manures being preferable under most conditions. If grain straw is not properly supplemented with chemical nitrogen, the trees may suffer from lack of nitrogen while the straw is decomposing. Tree prunings, sawdust, shavings, and other coarse materials which decompose slowly contribute to the humus content of soil, but they contain very little nitrogen and will usually require supplementary nitrogen, especially if worked into the soil.

Carry out a fertilizer program. For newly planted citrus trees, scatter about 1 ounce of a chemical nitrogen carrier in a furrow or basin around the tree before irrigation; calcium nitrate or sodium nitrate will give best results for the first year or two. Repeat this 3 or 4 times during the season, and increase the amount each year until the orchard is receiving 200 pounds per acre of actual nitrogen per year.

For bearing orchards, the application of 200 pounds per acre from a chemical source is recommended. This chemical may be applied all at one time in late winter or early spring, but if the soil is subject to leaching it will give better results if divided into several lots and applied at intervals during the season. In all instances, apply the nitrogen evenly to as much of the soil surface as possible, and adjust the amount used according to experience in each orchard. Materials applied after the rains are over will give the best results if scattered in the furrow bottoms before irrigation, or if dissolved in the irrigation water.

Broadcast 5 tons per acre of good dairy manure, or other material containing equivalent amounts of nitrogen and organic matter, as evenly as possible over the whole soil area in late summer or fall. Manure is especially important where there is a possible deficiency of phosphorus or potassium. As indicated in the table (page 25), 5 tons of bulky organic matter will provide 80 to 200 lb. of nitrogen, 50 to 200 lb. of phosphate (P_2O_5), and 80 to 270 lb. of potash (K_2O), plus 3,000 to 6,000 lb. of organic matter.

For use of a winter covercrop see the next section.

When deficiencies of zinc, copper, or manganese occur, they can be supplied most effectively as sprays. Soil applications in California are ineffective, expensive, and frequently harmful to the trees. When zinc is required, the safest formula is 5 pounds of zinc sulfate and 2½ pounds of hydrated lime or soda ash to 100 gallons of water. You may also use zinc oxide at the rate of 2 or 3 pounds per 100 gallons of water, but this material occasionally causes burning of leaves and fruit. Zinc oxide may be combined with certain sprays, but you should always follow the recommendation of the spray manufacturers. Treatment may be applied at any time, but it is most effective before the first flush of spring growth. Repeat it often enough to prevent the appearance of mottle-leaf symptoms.

For supplying copper, use a 3–3–100 bordeaux mixture—that is, 3 pounds of copper sulfate and 3 pounds of hydrated lime to 100 gallons of water. Do not use soda ash with copper sprays. Use reduced concentrations in areas subject to injury from copper sprays. A mixture of 1 pound of copper sulfate, 5 pounds of zinc sulfate, and 4 pounds of hydrated lime to 100 gallons of water is recommended. To supply manganese, use 1 or 2 pounds of manganese sulfate to 100 gallons of water. No lime or soda ash is needed.

In using nutritional sprays, it is not necessary to drench the trees; 5 to 8 gallons per mature tree is usually enough, but the material should be distributed evenly over the whole tree. Where deficiencies are known to occur, make applications often enough to prevent the reappearance of starvation symptoms. This will mean one annual treatment in most cases; with manganese, two treatments per year may be necessary. Both copper and manganese increase the susceptibility of citrus trees to fumigation injury, and where they have been used fumigation should not follow for several months. It is wise to fumigate a few test trees before treating the whole orchard.

Adequate fertilization is essential to profitable citrus production, but it can be effective only when irrigation, pest control, and other operations are properly attended to.

Covercrops and green manures. The general use of winter covercrops in citrus orchards in California has aided in maintaining soil fertility. These crops also help prevent soil erosion in winter, breaking up plow sole, and generally improving the physical condition of the soil. A covercrop is a disadvantage during the winter months because it results in somewhat lower temperature and interference with orchard-heating operations.

Do not regard a green manure as a substitute for animal manure. Both supply organic matter, but the latter supplies nitrogen, phosphorus, potash, and other minerals from external sources.

In most sections the advantages of covercrops and green manures far outweigh the disadvantages. Their beneficial effects, in combination with fertilization, have been clearly shown in numerous experiments conducted in groves located on a wide range of soil types. There has generally been a very substantial increase in yield where nitrogen has been applied in combination with a winter covercrop.

The covercrops most commonly used in California at present are purple vetch and *Melilotus indica,* which are legumes, and the mustards, which are nonlegumes. Natural weed growth is also used with good results by many growers. Oxalis and *Emex spinosa* occur each winter in almost pure stands in certain orchards and are spreading to new areas. Fortunately, they appear to be good covercrops, although they are not legumes.

Purple vetch is usually seeded with a drill at the rate of 25 to 30 pounds per acre—or broadcast and harrowed in just before furrowing out for irrigation. If seeded with 10 pounds of oats per acre, the yield is usually increased. Late September or early October is the best time in which to seed.

Turning under a covercrop in an orange orchard.

Small seeds, such as melilotus and mustard, do best if broadcast after furrowing out and just before irrigation. *Melilotus indica* is seeded, 10 to 15 pounds per acre in late September or early October. White mustard (*Brassica alba*) does best on the lighter soils, but its hollow stem is easily damaged by such operations as picking and orchard heating. It is seeded, 8 to 10 pounds per acre, from the first of September through October. Brown mustard, or Trieste mustard (*Brassica nigra*), is seeded 6 to 8 pounds per acre, from September 1 through October. It has a solid stem and usually recovers from the trampling incident to orchard operations. When natural growth is used as a covercrop, it is necessary only to omit fall tillage and allow weeds to develop.

Regardless of their condition, turn winter covercrops under as soon as possible after the middle of February. If the covercrop produces too much growth, or if it begins to mature before the soil is in condition for disking, mow it or break it down with a drag to retard its development until the soil is ready to work.

As we pointed out in the discussion on fertilization, large amounts of undecomposed organic matter may seriously reduce the availability of nitrogen. For this reason avoid excessive covercrop growth, and do not permit any covercrop to become mature and woody. Covercrops are beneficial only when properly managed.

Summer covercrops. We do not recommend summer covercrops for general use, because they compete with the trees for both water and fertility. However, a limited amount of summer weed growth is usually permitted to develop between cultivations, since its complete control would require excessive tillage.

Permanent covercrops. They have been used in a few orchards during the past 40 years. The practice has not been generally successful, but in the coastal areas a few orchards are being operated with success under this system. Permanent covercrops can be recommended only on deep, well-drained soils in the

coastal areas, where erosion makes conventional methods impractical.

Intercropping young orchards

In sections having rich soil and an abundant water supply, growing vegetable crops between the rows of young citrus orchard trees has proved to be a successful practice during the first 4 or 5 years after the trees are planted.

Lima beans and lettuce are the two principal vegetable intercrops grown, although flower crops, many kinds of garden vegetables, and small fruits (such as strawberries and bush berries) are occasionally grown. In desert areas an intercrop protects the young tree from intense radiation and results in improved tree growth.

For best results, do not continue the practice of intercropping beyond the fourth or fifth year. When intercrops are planted, take care to maintain suitable conditions for the trees at all times.

To cultivate or not to cultivate

Cultivation is a useful orchard operation, but if carried to excess it can be very harmful. The most important reasons for cultivating citrus orchard soils are to control weeds, which compete with the trees for fertility and moisture, to prepare irrigation works, and to incorporate covercrop and bulky organic fertilizers with the soil. Avoid all deep cultivation because it destroys roots. Keep in mind the fact that citrus trees feed on that part of the soil which is not cultivated.

All forms of tillage including cultivation tend to destroy soil structure and cause water to penetrate less readily. Often a hard, impervious layer known as plow sole develops a few inches below the soil surface; and, in extreme cases, this is serious enough to prevent adequate penetration of irrigation water. This effect can be minimized by avoiding tillage when the soil is wet, by applying organic matter, and by growing covercrops. Do not use mechanical means of controlling plow sole, because the results are only temporary and the operation will probably cause serious injury to the root system of the trees.

The common method of cultivation in California citrus orchards is to disk the

An intercrop of lima beans in a Valencia grove.

A tractor-mounted weed spraying rig, typical of those used in nontillage operations.

soil as soon as possible after the winter rains, usually in the latter part of February or the first part of March. Subsequent cultivation is done with a disk or a springtooth harrow, after every second or third irrigation until the sowing of the winter covercrop in the fall.

Nontillage. In California an increasing number of citrus orchards are now being operated without disturbance of the soil by tillage. Two methods are in use: In one, a permanent covercrop is maintained—this is feasible only under special conditions. In the other, weed growth is eliminated, and the soil remains more or less bare at all times. In orchards operated under this system the weeds are destroyed by a spray of orchard-heater oil or some other suitable herbicide; this process is sometimes supplemented by hand-hoeing. In a few orchards the weeds are eliminated entirely by hand-hoeing, without the use of herbicides. This is not usually feasible until the weeds have been pretty well eliminated for several seasons through the use of the spray method.

Experience has not yet shown how generally nontillage can be applied. The cost is greater for the first 2 or 3 years, but subsequent costs under good management will compare favorably with those under conventional tillage. Many advantages are claimed for this method of soil management, but the most important is an improvement in soil structure. This condition results in better water penetration and more favorable conditions for root growth.

Frost protection

Since all citrus districts in California are subject to occasional frosts, some means of protecting the trees and fruit may prove advisable. Orchard heating will not be profitable in all locations; the grower, when considering the advisability of providing frost protection, must determine whether or not heating is likely to pay in his particular case. Records of weather conditions in past years are available from the United States Fruit Frost Service or from your University of California Farm Advisor.

A study of weather conditions over a 10-year period may show that damaging frosts seldom occur, and that the cost of

installing and maintaining heating equipment would be greater than the probable loss of the crop. In some localities, frosts may occur so frequently that the cost of heating would exceed the probable returns from the crop.

If such a study indicates that frost protection will pay, two kinds of equipment are available, orchard heaters and wind machines. Orchard heaters provide the most dependable protection. They are not subject to serious mechanical trouble, and they continue to give heat regardless of atmospheric conditions. A total of 50 to 75 oil heaters of 9-gallon capacity, or 100 to 125 solid-fuel heaters, are required per acre.

An adequate supply of fuel is just as important as the heaters themselves. When oil is used, it is best to have all heaters full besides storage on the ranch for 1,000 gallons per acre, with more when additional fuel is not easily obtained.

For solid-fuel heaters it is desirable to have 1,500 to 2,000 pounds of fuel per acre in the heaters, 1,500 to 2,000 pounds of fuel per acre stored near the heaters in the orchard, and at least 7½ tons per acre stored on the ranch. In an emergency, solid fuel is difficult to get; therefore adequate storage is essential. Fuel storage should be maintained at capacity, with heaters ready to operate not later than November 1.

Laboratory tests carried out by the Agricultural Experiment Station indicate that all of the heaters tested converted into heat practically 100 per cent of the fuel burned. The important differences in heaters are related, therefore, to cost, ease of operation and regulation, and ability to burn ordinary fuels without leaving excessive amounts of unburned residue and without producing excessive amounts of smoke.

Heaters for orchards should:

1. Burn with a minimum of smoke and soot in order to comply with present or possible future smoke-abatement laws.
2. Cost a reasonable amount.
3. Hold enough fuel to burn all night without being refueled.
4. Be capable of sufficient regulation to give the greatest heat just before sunrise, even though by this time the fuel in the reservoir is low.
5. Be able to burn the ordinary grades of fuel without leaving excessive unburned residues.
6. Be easy to light and regulate by inexperienced labor under all weather conditions.
7. Be easy to take apart, clean, and store.
8. Be so designed that they can be burned dry, without damage.
9. Be made of good material and show small annual depreciation.

The primary principle in orchard heating is that a large number of small fires are more effective than a small number of large fires. Heaters should be burned within their normal burning range. Otherwise they will produce excessive amounts of smoke and will clog with soot and be difficult to regulate and service.

It pays to continue heating, even when orchard temperatures cannot be kept above the danger point. Heating which has seemed futile in the face of extreme cold has often paid good returns in fruit saved and tree damage prevented.

Good organization of labor and an ade-

Where tillage is practiced, growers find it necessary to rig their equipment with a protector that lifts low branches out of harm's way.

quate supply of thermometers and other accessories are absolutely essential to success. Failure to provide ample fuel, obtain enough help, and continue heating operations through discouraging weather conditions accounts for much unsuccessful heating. Occasionally the weather may be too cold to save the fruit, but the saving in tree damage will be well worth the cost.

Wind machines generally give protection against light frosts, but they are not effective in case of a freeze. Under most conditions a wind machine supplemented by 10 to 20 heaters per acre will give adequate protection. The value of a wind machine depends largely on the power expended. Most installations provide 5 to 8 horsepower per acre.

Windbreaks

Well-placed, well-maintained, permanent windbreaks* of the right tree species are essential in citrus-growing areas situated in the path of prevailing or severe winds. Packing-house records kept over a series of years in Orange and San Bernardino counties demonstrate that groves with adequate wind protection consistently yield large crops of higher-quality fruit, and that tree vigor is more easily maintained. In some coastal areas protection of lemon groves from less severe but steady and cool ocean winds has shown similar advantage in higher yields of good-quality fruit.

The blue-gum eucalyptus, *Eucalyptus globulus*, is the most satisfactory windbreak tree for most citrus districts. It grows rapidly, attains a height of 60 to 100 feet, maintains a good mantle of foliage throughout the year, and is resistant to damage by frost, diseases, and insects pests. It sprouts vigorously after cutting or pruning, and is not easily damaged even when its roots are severely cut at intervals to prevent undue competition with orchard trees.

Monterey cypress, *Cupressus macrocarpa*, has been widely used as a wind-

* This section was contributed by Woodbridge Metcalf, Associate Professor of Forestry and Agriculturist in Agricultural Extension.

A young lemon grove with a windbreak of cypress.

break, particularly in districts near the coast. In recent years, however, many fine rows of cypress trees have died from attack by the cypress canker disease and cypress bark beetles, so that it can no longer be recommended. Inland varieties of cypress, such as *C. arizonica, C. Forbesii*, and *C. nevadensis*, are apparently more resistant to such attacks and are being tried as windbreaks. They are slower in growth and generally less hardy than blue-gum eucalyptus.

Desert athel, *Tamarix articulata*, is probably better suited to extremely hot, dry desert sections where eucalyptus does not thrive. This species can easily be propagated in place from cuttings and grows rapidly with minimum care. However, it reaches only moderate height, often breaks badly in severe winds, and requires more attention to side pruning than does eucalyptus. It also has a wide-spreading root system which must be kept in bounds by consistent root pruning. There is no advantage in planting this species where blue-gum eucalyptus will thrive.

Proper placing and adequate care and management of windbreaks are of sufficient importance in some windy sections to warrant handling by cooperative, community action. This is particularly true in the maintenance and use of the heavy equipment used in root and top pruning.

The zone of protection to orchard trees varies from 5 to 7 times the height of the windbreak. The ideal location for windbreaks is at right angles to the direction of the severe winds, and there is a decided advantage in consistent planting of rows of trees throughout entire orchard areas. Most owners favor planting of the windbreaks along property lines which, in many instances, are not athwart the wind direction. This will often leave a part of the grove without adequate wind protection, so that trees in this area may suffer severe wind damage. The "grille method" of planting has been proposed to correct this condition and at the same time avoid interference with cultural operations.

It is evident, therefore, that a windbreak averaging 60 feet in height will protect a zone from 300 to 400 feet in width. Thus the most advantageous spacing will be at approximately 330 feet, which necessitates the planting of two windbreaks across each square 10-acre grove. The outside windbreak should be planted from 2 to 4 feet inside the property line, and the center row will take the place of one row of orange trees.

Plantings adjacent to an orchard should be made far enough inside the property line to provide working space of 12 to 15 feet. One-tenth of a well-protected orchard is devoted to the windbreak trees. This may seem like a heavy investment, but it has paid excellent dividends over large areas.

Windbreak trees respond to the same care and management required by the orchard itself. Use sturdy plants of eucalyptus, about 12 inches in height and with a normal and *uncramped* root system. Trees taller than 18 inches transplant with difficulty. Either a 5- or 6-foot spacing in the row can be used. Sonetimes a double row is essential if the windward side of the grove is exposed to unimpeded wind action.

If sturdy trees of maximum height and good foliage are to be maintained, the same schedule of cultivation, fertilization, and irrigation should be followed for the windbreak as for the orchard. Pruning back of alternate trees may be desirable in certain sections, in order to induce branching and make a denser layer of foliage. In addition, consistent root pruning with heavy, tractor-drawn equipment is usually advisable at intervals of two to three years to minimize root competition.

Artificial windbreaks have been constructed by some growers, to create immediate protection for valuable groves without waiting for eucalyptus trees to grow. These wooden structures of 3-inch slats require sturdy and well-braced frames of at least 2 × 6 inch timbers and cost from $2.50 to $6.00 per foot of

length. The maximum feasible height of such structures is less than half that of a row of full-grown eucalyptus trees. Not only is their deterioration high but they are also unsightly. Their advantages are immediate protection of the orchard and fuller utilization of the ground by orchard trees. On the basis of these calculations, it would require four such slat windbreaks to protect adequately the orchard trees on a square 10-acre block.

Pruning

This is one of the less important operations in citrus growing, but if properly carried out it contributes to the economy of production and may improve the quality of the fruit. If carried to excess, yields will be reduced.

An excessive accumulation of dead wood interferes with picking, pest control, and other operations involved in tree care. It may also interfere with the proper development of new growth and the set of inside fruit. A reasonable amount of pruning to remove dead and weak wood is therefore desirable.

Normal citrus trees produce vigorous shoots which tend to become tangled with the older branches. This growth can be controlled by bending it down and pulling it to the outside of the tree. Removal of vigorous wood should be confined to growth which cannot be controlled by other means—for example, growth which develops on the trunk or on the main frame and cannot be used to improve the structure of the tree. Excessive cutting of this type of wood only complicates the problem. Local stimulation of growth results in continued heavy production of new growth where the cuts are made. If any considerable amount of such wood must be removed, it should be done over a period of 2 or 3 years.

Old trees may require moderate pruning to stimulate growth. Such pruning should be done, however, only when the desired response cannot be obtained by fertilization or by improvement in the methods of irrigation, pest control, or soil management.

Removal of good wood to "let light into the trees" will usually result in reduced yields. This kind of pruning causes the tree to spend its energy to replace the lost foliage. Any attempt to force a tree into an unnatural type of growth can be expected to reduce yields.

Diseased or injured trees may benefit from pruning, but this depends on the nature of the disease or injury. Trees which have had their root systems damaged by rodents, by excessive irrigation, or by other causes will usually respond favorably to heavy pruning. However, trees whose leaf surface has been inpaired by insect damage, frost, wind, disease, or injurious sprays may be adversely affected even by light pruning.

Citrus trees often become crowded, with the result that the lower branches are shaded out. This results in increased harvesting costs, and often in decreased yields. Once this has occurred, there is no good way to restore the trees to satisfactory size without serious loss of crop. It is therefore good practice when trees begin to crowd to institute a program of annual pruning, which will limit tree size enough to prevent the lower limbs from being shaded out. In close plantings it may be best to relieve the condition by removing trees rather than by pruning.

The best time to prune, from the standpoint of the tree, is just before growth starts in the spring. This practice gives the tree use of its full leaf surface in winter and insures quick replacement of lost foliage by the spring flush of growth. From a practical standpoint, the work must be done at a time which fits into the general management program.

Light pruning may be done at almost any time, but should generally be avoided in late summer and fall. A light annual pruning is much better than an occasional heavy one. Excessive pruning reduces yields and should always be avoided.

Experiments in the pruning of se-

verely frost-damaged citrus trees have been carried on after nearly every freeze. These experiments have shown that pruning should be delayed for at least 6 months or a year after a freeze. The extent of the damage will be known by that time, and unnecessary pruning can be avoided. The picture below illustrates the advantages of delayed pruning. The lemon tree, which shows an unusual degree of recovery was not pruned until a year after the freeze that occurred during the winter of 1921–22.

Yield, size, or quality of oranges are little improved as a direct result of pruning normal trees. It is necessary, therefore, to justify pruning of oranges on some basis other than crop improvement. In commercial orchards, grapefruit receives even less pruning than oranges, but lemons require more. A certain limitation of a lemon crop by pruning usually improves the size and quality of fruit, and we therefore recommend moderate annual pruning.

Picking

Harvesting is one of the most important of the many handling operations to which citrus fruits are subjected. The care with which they are picked determines their length of life and the condition in which they reach the markets. Very slight skin punctures, bruises, clipper cuts, and careless handling or dropping into boxes result in losses because molds and fungi enter the tissues at such places and cause decay of the entire fruit. Many years of intensive study and carefully conducted experiments in picking and handling citrus fruits have proved that decay is increased by careless handling of the fruit in the grove and the packing house, and in transit to markets.

Picking is usually carried on by carefully trained crews, under the direction of an experienced picking foreman employed by the growers' association. The small operator rarely harvests his own fruit; only the large operators find it practical to have their own picking crews.

Left: Photo of a lemon tree taken shortly after the freeze that occurred during the winter of 1921–22. Right: the same tree after one year's growth. At this point it is time to remove the dead wood.

DISEASES AND PESTS . . .

Avoid trouble by periodical inspection and use of approved control measures.

DISEASES

Citrus trees in California are subject to a number of injurious diseases. Only the more important ones can be listed here. For detailed information, consult the special publications listed on the back page.

Psorosis, also called scaly bark, is the most common of the virus diseases attacking citrus trees in California. It is most destructive to the sweet orange, grapefruit, and mandarin, but is carried and transmitted by the lemon, lime, sour orange—indeed, most likely by all citrus species.

Young, growing leaves of affected trees show small, clear areas which usually disappear as the leaves mature. They do not show at all seasons, or in all leaves. They may be small flecks or may be long and narrow areas; occasionally they produce a pattern resembling an oak leaf. This symptom appears in all species of citrus, but is difficult to detect without experience. In lemons the virus may cause uneven growth in the leaves and fruit; this results in rough fruit and crinkly leaves.

As trees of the sweet orange, grapefruit, and mandarin mature, the virus causes local areas of outer bark to die and break away in small irregular-shaped scales. Only the surface of the bark is killed; new bark forms underneath and continues to scale off. Frequently pockets of gum are formed under the bark, and beads of gum appear in the affected areas. As the areas of affected bark enlarge, the wood becomes stained, the top begins to die back, and the trees gradually cease to produce.

In addition to these symptoms, the more virulent forms of the virus may cause yellowish circular areas to develop on mature leaves and fruit. These occasionally resemble ringworm. Concave gummosis and blind pocket are closely related to psorosis and are caused by variations of the same virus or by closely related viruses. The bark symptoms differ, but the leaf symptoms are the same.

The virus of psorosis is transmitted principally by means of buds taken from infected trees, and occasionally by natural grafts which take place between roots of adjacent trees. Other means may exist, but they are not known. It is therefore possible to avoid the disease by producing nursery trees propagated with buds from virus-free trees.

As an aid to the citrus industry, the Bureau of Nursery Service of the State of California has arranged to register trees which are to be used as virus-free sources of budwood. More than 1,000 such trees are now registered.

After proper inspection, trees found to be free of virus diseases are tagged and registered in Sacramento. These trees are available to nurserymen as sources of budwood. *If growers demand nursery trees produced with buds taken from registered trees, the occurrence of psorosis and similar diseases will be reduced to a minimum.*

No cure is known for psorosis, but where the bark is just beginning to scale, the removal of the outer layer of affected bark, if properly done, will prolong the productive life of the tree. This may be done mechanically by scraping or by chemical means. Treatment is recommended only in early stages of the disease and on vigorous trees. Trees which de-

velop bark symptoms of the disease early in life (5 to 7 years) and trees which show deterioration in the top should, in most cases, be removed.

Brown-rot gummosis, also called foot rot, occurs on all citrus varieties in California. The most common form is caused by the brown-rot fungus, *Phytophthora citophthora,* and related species. This fungus attacks and kills the bark at or near the ground level. Large quantities of gum are usually produced when the infection is aboveground. For this reason the disease is commonly referred to as gummosis. Under some conditions the fungus may attack the upper part of the trunk, or even limbs and twigs in the top of the tree.

Lime and lemon varieties are most susceptible to the brown-rot fungus; orange, grapefruit, and mandarin varieties are somewhat resistant. Of the common stocks, sour orange, Cleopatra mandarin, and trifoliate orange are most resistant. Sweet orange, Rough lemon, and grapefruit are intermediate. Infection is favored when wet soil remains in contact with the bark.

To avoid gummosis, plant trees high enough so that, after settling, the point at which the first lateral roots branch out is at the ground level. On heavy soil it is especially important to use stocks which are resistant to the disease. With older trees all soil should be removed from around the trunk down to, or even below, the first lateral roots; keep this area as dry as possible. Do not apply water around the trunk of the tree.

As an additional precaution the trunk and exposed roots may be painted with a bordeaux wash of equal parts of copper sulfate and hydrated lime, with water enough to make a thick paint. Apply this wash each year before the rainy season begins.

Treatment consists of exposing the crown roots and cutting away the dead bark and about ½ inch of the adjacent live bark. No wood should be removed. Disinfect the wound with potassium permanganate (1 teaspoonful to 1 pint of water) and, when the wound is thoroughly dry, apply a good pruning compound to the exposed wood. Do not replace the soil after treatment. Where the bark has been killed more than half way around, it is best to remove the tree and replant.

A number of other fungi, such as *Diplodia*, *Botrytis*, *Dothiorella*, and *Sclerotinia* may cause, or assist in causing, foot rot and gummosis, but treatment is the same for all.

Brown rot of fruit. This is an important disease of citrus fruits in California. It is caused by several species of *Phytophthora*, the fungi which cause brown-rot gummosis. Spores of the fungus are splashed by rain onto fruit on the lower branches, and a decay is produced which leaves the fruit firm but turns the rind light-brown color.

The disease is favored by rain and long periods of wet weather. Lemons are most seriously affected, but all citrus varieties are susceptible. The disease is prevented by thoroughly spraying all fruit within 3 or 4 feet of the ground with a bordeaux mixture. Weeds and soil near the skirts of the trees should also be thoroughly sprayed. Apply the spray before the rainy season, in early November.

Where brown rot is serious, use 6 pounds of copper sulfate and 6 pounds of hydrated lime to 100 gallons of water. Under usual conditions, half this strength of bordeaux is sufficient. If the trees are to be fumigated soon, the following formula may be used: zinc sulfate 5 lb.; copper sulfate, 1 lb.; hydrated lime, 4 lb.; water, 100 gal. It is important to cover the fruit thoroughly with spray.

In certain areas copper-bearing sprays have caused severe burning of fruit and foliage and some damage to twigs. Where this has occurred use the formula suggested above for trees to be fumigated. In some cases it may be necessary to discontinue the use of copper. No other

material can be recommended now but several new organic fungicides are being tried and results are very encouraging.

Oak root fungus. In limited areas of California, root rot may be caused by oak root fungus, *Armillaria mellea*. This fungus is often present where oak trees have been removed, or where flood waters have deposited infected wood. It causes a moist decay of bark and wood and can be identified by the white, fan-shaped fungus growth which develops in and under the bark, or by dark, rootlike strands which develop on the surface of roots. During late fall or early winter, groups of light-brown toadstools are produced.

All citrus varieties are affected. The disease can sometimes be retarded by exposing the crown roots and allowing them to dry out, but no cure is known. The fungus in the soil must be destroyed by fumigation before replanting.

After the affected area has been isolated, carbon disulfide is used in holes 8 inches deep and 18 inches apart over all of the infected area. The usual charge is 2 ounces per hole. At points where trees are removed, it is advisable to put three or four extra charges of 6 ounces in holes 4 or 5 feet deep. The holes are plugged as soon as the carbon disulfide is applied.

For the best results, the soil should be as dry as possible and the top 3 or 4 inches should be wetted just before or immediately after treatment. All plants in the treated area are killed, but replanting can begin in 6 to 8 weeks.

Shell bark of lemons. Shell bark is found in all citrus-growing areas of California, but is known only on lemons. It affects the outer layers of trunk bark on older trees. The affected bark dies and breaks away from the trunk in rather large vertical strips while new bark forms underneath. During the more active stages of the disease, the top of the tree becomes thin and off-color and may show some dieback of twigs. In some cases only part of the treetop is affected at any one time.

The disease seems to be favored in the more humid areas. It usually starts at the bud union and gradually involves the whole trunk; it may affect the main branches of old trees. Lemon varieties differ in their susceptibility and may develop the disease any time between 10 and 30 years of age. Eureka lemon is more susceptable than Lisbon. The cause has not been determined. No satisfactory treatment for this disease has been found.

Dry bark is a disease of lemons found principally near the coast. Areas of dead, dry bark appear on the trunk and main limbs of the trees. These dead areas enlarge until the tree becomes unproductive. Affected trees may be destroyed in a few months, or they may continue to produce some fruit for several years. Severe pruning may temporarily increase production, but it is not a cure. The disease is not fully understood. It is believed by some to be a severe phase of shell bark. No treatment is known, but the following suggestion may delay the disease in new plantings:

When planting new trees be sure the buds are from trees growing under the same environment as the new orchard. Parent trees should be free from disease and at least 25 years old.

Water spot. In California, water spot occurs principally on Washington Navel oranges. During long, wet spells, late in the season, water is absorbed by the white portion of the rind through openings caused by injuries. The resultant swelling causes minute splits in the rind, which permit more water to be absorbed. This condition, together with oil liberated from the injured rind, causes the cells to break down. If dry weather soon follows, depressed brown scars result. Fruit so affected is unusually subject to decay and is not suitable for shipment. If moist weather continues, various fungi attack the fruit and cause rapid decay in the orchard.

Susceptibility to water spot increases as maturity advances. It is greatly increased by mechanical injuries, by ice

which forms on the fruit in cold weather, or by oil sprays applied to the fruit. No practical control is known, but early picking and orchard practices performed carefully to avoid fruit injury are important in reducing loss from water spot.

Quick decline. This virus disease was first found in California in the winter of 1939–40, but it had evidently been present for some time before that date. It is characterized by root decay, which begins at the root tips and progresses back to the large roots. This is followed by symptoms in the top which resemble those produced by gophers, gummosis, or other cause—in fact, the trees are girdled. The virus or its products destroy the conductive tissues in the bark of the rootstock. The tree may die within a few days after the first above-ground symptoms are observed, but usually the decline occurs over a period of several months. The trees may not actually die for several years.

In orchards the quick-decline virus appears to be spread by an insect carrier. Many species of insects have been tested, but only the melon aphis, *Aphis gossypii* (Glover), has been found capable of transmitting it. The virus is present in all trees propagated with buds taken from infected trees.

All citrus species are believed to be capable of carrying it. In commercial orchards only sweet orange on sour stock have been affected, but in experimental plantings some seedlings and many combinations of stock and scion have been injured by the virus. This work has not progressed far enough to be discussed here. Diseased trees should be removed promptly and replaced with trees which will tolerate the virus.

PESTS

The control of pests is one of the most expensive operations in the production of citrus fruits, also one of the most difficult because local and seasonal differences in climate must be taken into account in all control work. For this reason, general recommendations have little value; and it is always desirable to consult the University of California Farm Advisor, an agricultural inspector, or other authority before doing control work. The following is a brief description of the more important pests, together with a statement of their distribution.

Insect pests

California red scale. The red scale, *Aonidiella aurantii* (Mask.), is present in most citrus-growing areas of California. It is found on the leaves, twigs, and fruit, and produces a toxic substance which causes a more or less general killing of leaves and twigs. The scale is reddish-brown, almost round, and a little over $\frac{1}{12}$ inch in diameter. On green fruit and leaves it causes a yellow spot somewhat larger than the scale; on leaves the spot extends through to the opposite side. In certain areas this scale has developed a resistance to hydrocyanic acid gas; this makes control very difficult. Control measures should always be taken before the scale becomes abundant.

Yellow scale. In many citrus districts the yellow scale, *Aonidiella citrina* (Coq.), is found, and it is frequently mixed with red scale. At present it is more abundant in certain inland areas than is red scale. It is found principally on leaves and fruits, although present on twigs to a very limited extent.

Only by careful examination is it possible to distinguish between yellow scale and red scale. Yellow scale produces a more marked yellow spot on leaves and fruit. It may cause heavy leaf drop, but does not cause the serious dieback which results from red-scale attacks. In limited areas of Tulare County yellow scale is also known to be resistant to hydrocyanic acid gas.

Purple scale. In the coastal areas of California the purple scale, *Lepidosaphes beckii* (Newm.), is a serious pest on citrus trees. It is found on leaves, twigs, and fruit. The scale produces a toxic substance

A labor saving type of spray rig widely used in citrus pest control operations.

which kills the more heavily infested parts of the tree. Its presence can often be detected at a distance by these dead areas. This scale can be recognized by the narrow, oystershell-shaped female about $\frac{1}{8}$ inch long and dark purplish in color.

Citricola scale. The citricola scale, *Coccus pseudomagnoliarum* (Kuw.), is present in most interior districts. The adult female is gray, oblong, and about $\frac{3}{16}$ inch long. It produces honeydew, which causes sooty mold to grow on the leaves and fruit.

Black scale. Black scale, *Saissetia oleae* (Bern.), is widely distributed in coastal and intermediate areas. It is most easily recognized by the female, which is dark brown or black, hemispherical, and about $\frac{1}{8}$ to $\frac{3}{16}$ inch long. Most specimens have ridges on the back which form the letter "H." It may be found on leaves, twigs, and sometimes fruit. It produces honeydew; this, in turn, serves as a medium for the growth of a sooty mold, which reduces the effectiveness of leaves and is difficult and expensive to remove from fruit.

Citrus thrips. The citrus thrips, *Scirtothrips citri* (Moult.), is a pest in the interior and intermediate areas of California. It is a small, light-yellow insect, about $\frac{1}{30}$ inch in length, which rasps the fruit and leaves in the very young stages. Scarred and distorted leaves result, as well as multiple buds, and fruit which has an irregular circular scar around the stem end and irregular scars on other parts.

Thrips begin to feed on tender foliage early in the spring and continue throughout the growing season. Injury to fruit begins at about the time petals fall from the bloom and continues until the fruit is about 1 inch in diameter.

Citrus red mite. One of the serious pests is the citrus red mite, *Paratetranychus citri* (McG.). It attacks leaves and fruit and causes them to take on a gray, dry appearance. The mite is red and dif-

ficult to see because of its very small size. It has gradually moved inland until it is now present in most of the citrus-producing areas of California. Treatment should be given as soon as the mites are observed.

Citrus bud mite. The citrus bud mite, *Eriophyes sheldoni* (Ewing), is a pest in California coastal areas and appears to be advancing into intermediate areas. It is more important as a pest on lemons than on oranges. It is difficult to observe even with a good hand lens, but its presence is recognized by the distorted leaves and fruit which result from its attack.

Aphids of several species attack citrus in all districts, but they are of most importance in coastal and intermediate areas. They are not a serious pest on lemons, but often on oranges and grapefruit, especially when the trees are young.

Aphids feed on young growth, including blossoms. This results in tightly curled leaves and reduced growth. They have many enemies and are often destroyed by unfavorable weather, but they have such ability to multiply that they are capable of doing extensive damage within short periods of time.

Mealybugs. Mealybugs occur principally in coastal areas. Although commonly kept in check by their natural enemies, they occasionally do considerable damage. They are difficult to control by chemical means.

Orange worms. Several species of worms attack citrus fruits, most important being the orange tortrix, *Argyrotaenia citrana* (Fern.). They damage the fruit by feeding on the rind. On young fruits they cause a scar around the button. Orange worms are not usually a pest outside of coastal areas.

Snails. Snails are often a serious pest in the coastal areas. They feed on the leaves and bark of the tree and damage fruit by eating holes in the rind.

Miscellaneous minor pests. The following insects and mites are occasionally of importance on citrus trees: soft (brown) scale, greenhouse thrips, potato leafhopper, Argentine ant, Fuller rose beetle, orange holcocera, pink scavenger worm, six-spotted mite, citrus rust mite, fruit-tree leaf roller, katydids, Lewis mite, and cottony cushion scale.

Biological control. All of the insects attacking citrus trees are subject to diseases and to destruction by their insect enemies. Cottony cushion scale, soft (brown) scale, and citrophilus mealybugs are kept under control by their enemies.

Occasionally the natural balance is upset by unwise use of insecticides or other causes, and these pests increase temporarily. Citricola scale, black scale, and mealybugs other than citrophilus are controlled by natural enemies in certain districts, but in some areas and at certain times they require chemical control measures. Recently introduced parasites of purple scale are giving promising results at this time. There are a number of minor citrus pests which would be much more destructive if they were not under biological control. A continuous effort is being made to find new enemies of citrus pests and to devise methods for increasing the effectiveness of those already present.

Animal pests

Gophers are one of the most important and destructive pests of citrus trees, frequently girdling the trunk and main roots below the soil level. The damage is usually unnoticed until the tree begins to lose its leaves and die back. Except in the areas where quick decline is most active, more trees are killed by gophers than by any other cause. It is necessary to be continuously on the lookout for signs of gophers in the orchard and to poison and trap them before the trees are damaged.

Field mice sometimes girdle the trees just above the soil level, especially in the vicinity of vacant land. They can usually be controlled by clearing the litter from under the trees and scattering poisoned grain in the orchard.

KEEP ACCURATE RECORDS . . .

Production costs let you know where you stand at all times.

Production Costs

The California Citrus League has conducted studies on a large acreage and for a long period on the cultural costs of producing oranges and lemons in California. These studies suggest many ways to lower certain fixed and fluctuating charges, but the effectiveness of these reductions is up to you. The successful grower of the future will be the one who can keep his production costs at a minimum, for the increased plantings of the past few years will insure the production of larger supplies of fruit, which will probably mean lower returns to the grower.

Cost-of-production studies are also being carried on by the University of California Farm Advisors in cooperation with growers in their districts. Special studies are being made with profitable, unprofitable, and average groves in the citrus-growing areas. You can get detailed information from your local Farm Advisor for cost-of-production figures in groves similar to your own, and in your own locality.

It is extremely important to keep cost-account records. You should know at all times the cost of producing your crop. Citrus-fruit growing in California, thousands of miles from large market centers, is a complex and specialized industry. To be successful, you must have a great amount of foresight and energy. Attention to details may mean the difference between profit and loss for you and for the industry.

RECOMMENDED READING

The following publications are recommended for those who wish to learn more of the details of certain steps in citrus culture that have been touched on in this circular. While some of the publications listed may be currently out of print, most, if not all of them, are available in many libraries throughout the state.

Aldrich, D. G., and W. R. Schoonover
1951. Gypsum and other sulfur materials for soil conditioning. California Agr. Exp. Sta. Cir. **403**:1–12.

Bartholomew, Elbert T., and Walton B. Sinclair
1951. The lemon fruit: Its composition, physiology, and products. 163 p. University of California Press, Berkeley.

Bartholomew, E. T., W. B. Sinclair, and R. P. Horspool.
1950. Freeze injury and subsequent seasonal changes in Valencia oranges and grapefruit. California Agr. Exp. Sta. Bul. **719**:1–48.

Bartholomew, E. T., W. B. Sinclair, and F. M. Turrell
1941. Granulation of Valencia oranges. California Agr. Exp. Sta. Bul. **647**:1–63.

Bliss, D. E.
1944. Controlling armillaria root rot in citrus. California Agr. Exp. Sta. Leaf. **50**:1–7.

Ebeling, Walter
1950. Subtropical entomology. 747 p. Lithotype Process Co., San Francisco.

Fawcett, H. S.
1936. Citrus diseases and their control. 656 p. 2d ed. McGraw-Hill Book Co., New York.

Gardner, Kelsey B.
1950. The California Fruit Growers Exchange system. U. S. Farm Credit Admin. Cir. 135:1–124.

Hoos, Sidney, and R. E. Seltzer
1952. Lemons and lemon products: changing economic relationships, 1951–52. California Agr. Exp. Sta. Bul: 729:1–78.

Johnston, J. C., and Wallace Sullivan
1949. Eliminating tillage in citrus soil management. California Agr. Ext. Service Cir. 150:1–16.

Kepner, R. A.
1940. Operation of orchard heaters. California Agr. Exp. Sta. Bul: 643:1–32.
1950. The principles of orchard heating. California Agr. Exp. Sta. Cir. 400:1–10.
1951. Effectiveness of orchard heaters. California Agr. Exp. Sta. Bul. 723:1–30.

Klotz, L. J.
1950. Gum diseases of citrus in California. California Agr. Exp. Sta. Cir. 396:1–20.

Klotz, L. J., and H. S. Fawcett
1948. Color handbook of citrus diseases. 2d ed. revised and expanded. University of California Press, Berkeley. (51 color plates; looseleaf.)

Klotz, L. J. and others
1948. Water spot of navel oranges: studies of the problem to 1948. California Agr. Exp. Sta. Leaf. 65:1–6.

Mutual orange distributors
1947. A manual for citrus growers. 141 p. rev. ed. Edited by Willis Parker and others. Mutual Orange Distributors, Redlands, California.

Parker, E. R., and W. W. Jones
1951. Effects of fertilizers upon the yields, size, and quality of orange fruits. California Agr. Exp. Sta. Bul. 722:1–58.

Pillsbury, A. F., O. C. Compton, and W. E. Picker
1944. Irrigation-water requirements of citrus in the South Coastal Basin of California. California Agr. Exp. Sta. Bul. 686:1–19.

Quayle, H. J.
1941. Insects of citrus and other subtropical fruits. 583 p. Comstock Pub. Co., Ithaca, N. Y.

Samuels, J. K., and G. L. Capel
1951. Citrus packinghouse costs in California. U. S. Farm Credit Admin. Cir. 138:1–13.

Sinclair, W. B., and E. T. Bartholomew
1944. Effects of rootstock and environment on the composition of oranges and grapefruit. Hilgardia 16 (3) : 125–76.

Taylor, Colin A.
1941. Irrigation problems in citrus orchards. U. S. Dept. of Agriculture Farmers' Bul. 1876:1–34.

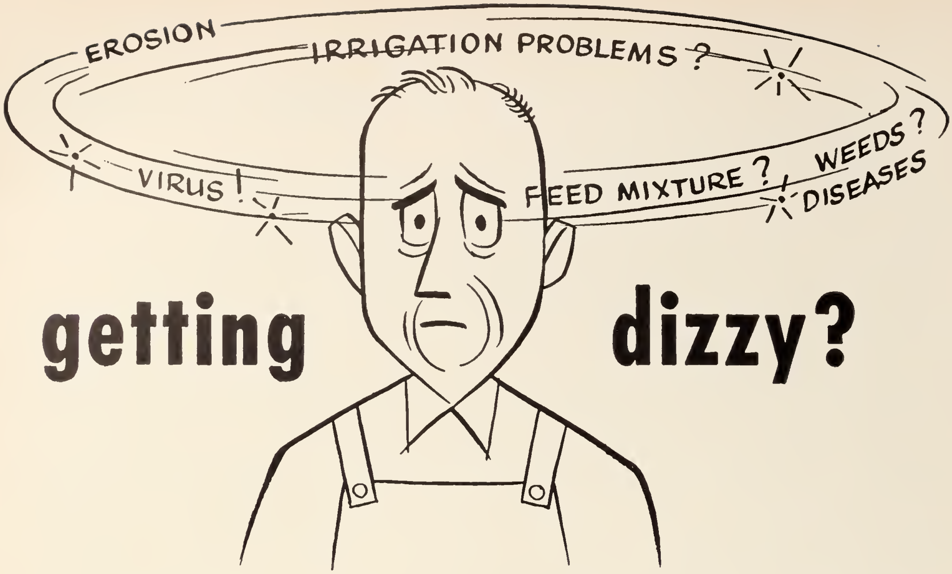
Webber, H. J., and L. D. Batchelor, eds.
1943–48. The citrus industry. V. I: History, botany, and breeding. V. II: The production of the crop. University of California Press, Berkeley. (2 volumes.)

ACKNOWLEDGMENTS

The author wishes to acknowledge with thanks the following University of California Farm Advisors who were helpful in providing some of the illustrations used in this circular: C. D. Gustafson of Orange County; R. G. Platt of Ventura County; B. E. Yarick, formerly of Los Angeles County; and Marvin Miller of Riverside County. The photos on pages 28, 30, and 40 are used through the courtesy of the Caterpillar Tractor Company.

Co-operative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture co-operating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. J. Earl Coke, Director, California Agricultural Extension Service.

10m-4,'53 (A2515) AA 141



getting dizzy?

IT JUST COULD BE . . .

that the farm problems troubling you have also troubled others.

And it's also possible that with a little help from the right source your problems can be eased, if not cured.

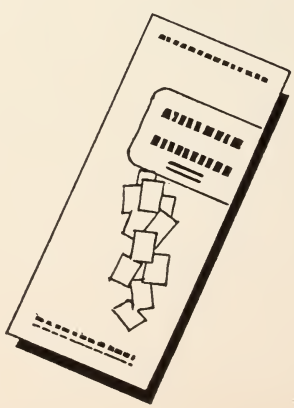
Here's how to go about getting help.

Take your problems to your County Farm Advisor. He's an agricultural specialist with a background of practical knowledge about farming in your locality. He will help you if he can . . . or he will get the information you need from someone who does know the answers.

Ask your Farm Advisor for a copy of AGRICULTURAL PUBLICATIONS—a catalog that lists the bulletins and circulars produced by the University of California College of Agriculture, or write to the address below.

You'll be amazed at the wide range of information covered in these publications.

Yes . . . it just could be that your problems aren't nearly as hard to solve as you think. Make use of the free services of your University.



Office of Agricultural Publications
22 Giannini Hall
University of California
Berkeley 4, California